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EFFECT OF DDT ON ANIMAL LIFE OF BULL'S ISLAND SOUTH CAROLINA

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The Bull's Island unit of the Cape Romain National Wildlife Refuge is situated between Georgetown and Charleston, South Carolina, in Charleston County. This barrier island, some 5,000 acres of woodland and marsh, lies three miles offshore, and is separated from the mainland by salt marsh and tidal creeks. It is well known for its semi-tropical appearing forest and its population of deer, raccoons, wild turkeys, waterfowl, and other wildlife.

A less desirable component of the fauna consists of ticks. Five species are present, the most abundant being the lone star tick (*Amblyomma americanum*). At the time of this experiment about 99 per cent of the ticks collected by dragging were of this species. Other ticks present on the island are *Dermacentor variabilis, Amblyomma maculatum, Ixodes scapularis,* and *I. texanus.* These parasites, with the possible exception of *I. texanus,* are potential vectors of diseases fatal to man. As a result of their great abundance, they have a devitalizing effect on much of the wildlife, even to the extent of causing the death of young deer and perhaps of wild turkeys. The irritation to human inhabitants and visitors to the island also has been severe in summer.

It has been the aim of the United States Fish and Wildlife Service, through the program administered by former Refuge Manager Andrew H. DuPre, to reduce the population of ticks in line with wildlife management objectives. Controlled burning, recognized generally as a limiting factor to the increase of ticks and chiggers, has not been successful here because of the topography and type of forest. Likewise, a seven-year program of animal host reduction, including the elimination of feral hogs and sheep and the reduction of native deer and raccoons, has not resulted in a major reduction of ticks. With the development of DDT (dichloro-diphenyl-trichloroethane) came the possibility of tick control through this medium. In 1946

[1] The following persons were helpful in identifying invertebrate animals listed in this paper: L. L. Buchanan, W. S. Fisher, C. T. Greene, A. B. Gurney, Carl Heinrich, Karl V. Krombein, B. E. Rees, R. I. Sailer, M. R. Smith, Alan Stone, and H. H. Swift of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture; Harold Rehder of the U. S. National Museum; E. B. Chamberlain, G. Robert Lunz, Jr., and E. B. Richardson of the Charleston Museum; S. F. Hildebrand of the Fish and Wildlife Service.

under a cooperative agreement between the United States Bureau of Entomology and Plant Quarantine and the Fish and Wildlife Service, it was planned to spray experimental plots on Bull's Island, testing for tick control and the effect on other animals. Messrs. C. N. Smith and H. K. Gouck, who were the field representatives of the Bureau of Entomology and Plant Quarantine, made detailed studies of the effect of the spraying on ticks.

FOREST ENVIRONMENT

Approximately 1,500 acres of the 5,000 comprising Bull's Island are wooded with a hammock-type forest dominated by pine, oak, and palmetto. This forest is the principal habitat of the ticks. The composition of much of the woodland studied was determined by a cruise of 10 per cent on 128 acres. The overstory of this mature forest, which has been subjected to only limited selective cutting, is composed of cabbage palmetto (*Sabal palmetto*), loblolly pine (*Pinus taeda*), laurel oak (*Quercus laurifolia*), live oak (*Quercus virginiana*), sweetgum (*Liquidambar styraciflua*), and small numbers of several other species. This permits an understory of shade-tolerant species such as the red bay (*Persea borbonia*), yaupon (*Ilex vomitoria*), young cabbage palmetto and holly (*Ilex opaca*). The most prominent topographic feature is the parallel rows of old low dunes now stabilized by forest growth. On ridges and slopes the common herbaceous plants are spike grass (*Uniola laxa*), nut rush (*Scleria triglomerata*), panic grasses (*Panicum* spp.), partridgeberry (*Mitchella repens*), and bedstraw (*Galium hispidulum*). In the poorly drained dune troughs, where standing water can be found much of the year, the ground may be nearly bare of vegetation or supporting such plants as switch cane (*Arundinaria tecta*), sawgrass (*Cladium jamaicense*), and dwarf palmetto (*Sabal minor*). The degree of growth here is greatly affected by the amount of sunlight reaching the forest floor or the amount of standing water.

Festooning the forest trees are the abundant vines of muscadine (*Vitis rotundifolia*), greenbriers (*Smilax* spp.), yellow jessamine (*Gelsemium sempervirens*), supple-jack (*Berchemia scandens*), peppervine (*Ampelopsis arborea*), woodbine (*Parthenocissus quinquefolia*), and poison ivy (*Toxicodendron radicans*); while from the tree trunks and limbs grow spanish moss (*Dendropogon usneoides*), mistletoe (*Phoradendron flavescens*) and the fern *Polypodium polypodioides*.

Measurements of trees surrounding an observation tower adjacent to the sprayed plots revealed the following data on forest height. However, these figures do not reflect conditions throughout the plots, particularly of pine stands on the best sites where they were taller.

Average cabbage palmettos	30 feet
Tallest cabbage palmettos	45 feet
Average live oaks	47 feet
Tallest live oaks	63 feet
Average loblolly pines	66 feet
Tallest loblolly pines	83 feet

SPRAYING PROCEDURE AND ITS EFFECT ON TICKS

Spraying, including one plot sprayed from the ground, was accomplished between April 18 and 22, 1946. Ten plots were laid out for study. These

were of varying acreages. Sixty-four of the sixty-eight acres in Plots A, B, and E were selected for study of the effect of DDT on forest animal life, particularly birds. Each of these plots received three pounds of DDT per acre. The effect on ticks was studied on all plots except J, which was a 64-acre unsprayed control plot established principally for the study of birds. Salt-marsh invertebrates and their reaction to DDT were studied on Plot G. Because of the proximity of these plots there was some overlap of poison application between A and B, and A and E, the total release above the dividing road approximating six pounds of DDT per acre.

Filter papers were placed on the forest floor to determine the amounts of DDT reaching the ground. These samples were analyzed for DDT deposition by Dr. James B. DeWitt, Chemist at the Patuxent Research Refuge, Laurel, Maryland. With DDT in solution in xylol or pine oil, and in some cases diluted with water, in total amounts ranging from 2.2 to 4.4 gallons per acre, it was found that only a small percentage of the three pounds sprayed above the tree tops reached the ground. On sites where the ground was completely exposed the highest recorded rate of deposit was .91 pound per acre. In situations where the aerial application was subject to screening by dense stands of trees and shrubs, the amount reaching the ground level was as low as .01 pound per acre. The average deposition on 59 filter papers placed at random in the woods was .14 pounds of DDT per acre.

This small amount of DDT, reaching the ground immediately after spraying eliminated many ticks. Rains subsequently may have washed down more DDT. The data on tick kill from Gouck and Smith (1947) are reproduced in Table 1. In their studies live ticks were collected before and after spraying by pulling cloth "drags" over prescribed distances, and counting the ticks attached. After the parasites were tallied they were released near the collecting point. Comparison of unsprayed and sprayed plots showed that a substantial initial kill could be made by airplane spraying of two to three pounds of DDT per acre, and that six weeks after spraying the abundance of ticks steadily decreased. According to Gouck and Smith control was 85 per cent complete six weeks after spraying. The degree of kill was directly proportional to the amount of DDT reaching the ground, as indicated by the greater kill on the "overlap" strips and on Plot H, where one pound per acre was placed more effectively by a ground operated pump.

Ground spraying was done with a model 64 Bean pump mounted on a truck. With 100 feet of half-inch hose an operator can work that far from either side of the truck, and can spray 25 feet to either side of the hose line. This sprayer operates at from 80 to 150 pounds pressure, with a semi-mist spray. Its operation is time-consuming and laborious in forest underbrush, one to two hours being required to spray an acre having a dense understory like that on Bull's Island. Compared to airplane spraying (and its requirement of plane, pilot and special techniques), it is possible to use less materials and apply them to the ground more effectively for a higher degree of tick con-

trol and without the effect of reducing arboreal insect populations. Ground spraying on Bull's Island was about 3 times as effective in controlling the ticks, as plane spraying. Technical grade DDT at the time of spraying cost 50 cents per pound; xylol, 27 cents per gallon; pine oil, $1.25 per gallon. Exact figures on the total cost of spraying were not kept, but Carroll N. Smith, by letter, estimates that the airplane spraying cost at least $2.00 per acre, counting materials (3 pounds of DDT), labor and plane. This estimate is based on the assumption that a solvent other than the more expensive pine oil is used. The cost of ground spraying with one pound of DDT (dissolved in 40 ounces of xylol and 8 ounces of Triton X-100 and emulsified in 100 gallons of water) was estimated to be $4.00 per acre. This is based on three hours labor, to mix and apply the spray, at the rate of $.75 for one man-hour. It is presumed that this method of application, using a tractor-mounted sprayer capable of blowing a low-level mist or dust greater distances through the woods, would be the best practice for areas similar to Bull's Island.

EFFECT ON INSECTS AND ARACHNIDS

Shortness of time prevented a more detailed study of insects and related invertebrates on the forest plots, but general notes were kept.

One of the most noticeable and welcome effects of spraying was the immediate and total elimination of mosquitoes of several species. One day after application no living mosquitoes were found in any of the sprayed plots; they remained common in unsprayed areas.

Within two and a half hours after airplane spraying many lepidopterous larvae and other soft-bodied insects started falling from the forest canopy, dead or dying. Some of the most common were larvae of the forest tent caterpillar (Lasciocampidae), measuring worms (Geometridae), hawk moths (Sphingidae), tussock-moths (Lymantriidae) and leaf-rollers (Tortricidae).

Prior to spraying it was observed that the forest floor litter supported a large population of wolf spiders (Lycosidae), wood roaches, beetles, crickets, grasshoppers, ants and harvestmen. Airplane spraying of three pounds of DDT per acre killed large numbers of the cricket *Acheta assimilis*, nymphs of the grasshoppers *Atlanticus* and *Amblycorypha*, the roach *Cariblatta lutea lutea*, and predaceous ground beetles of the genera *Calosoma*, *Pasimachus*, *Platynus* and *Selenophorus*.

Arboreal spiders deserted the tree foliage soon after spraying, as witnessed by the increase in low-level, "drift" webbing the day after spraying; whereas, the ground-dwelling wolf spiders were not so immediately affected, but began dying two to four days after spraying. Common species affected were *Lycosa avara*, *L. riparia* and *Schizocosa ocreata*.

In standing pools of water on the forest floor the spray ultimately killed large numbers of predaceous diving beetles (*Cybister fimbriolatus* and *Thermonectes basilaris*), water scavenger beetles (*Dibolocelus ovalis*, *Hydrochara obtusata*, *Tropisternus* sp.), and backswimmers (*Notonecta* spp.). The percentage of kill was particularly high in those pools over which the canopy was open, while many protected pools

showed no evidence of mortality from DDT.

In general, the destruction of insects was widespread and rapid, but of variable severity, with dipterous insects such as mosquitoes and certain lepidopterous larvae being especially susceptible. Some groups were scarcely affected. The duration of DDT's effectiveness was not measured for arboreal insects, but presumably successive rainfalls reduced the hazard for later generations. Mosquitoes gradually reappeared on the plots during the one month between April spraying and May observations. Cicadas, which emerged during the same period, were abundant and not noticeably affected. At the same time, DDT on the ground level was still effective, as indicated by the reduced populations of ticks.

TABLE 1.—POPULATION OF TICKS BEFORE AND AFTER DDT SPRAYING

Plots	Size of plots (Acres)	Treatment per acre (Pounds of DDT)	Ticks collected before treatment		Per cent of original infestation after DDT treatment					
					1–2 Days		15–20 Days		44–48 Days	
			Nymphs	Adults	Nymphs	Adults	Nymphs	Adults	Nymphs	Adults
A	29	3	1,524	305	*40*	*35*	*28*	*34*	*12*	*12*
B	18	3	801	200	*46*	*35*	*25*	*34*	*11*	*16*
Road A–B	Overlap	3–6	375	245	*26*	*17*	*2*	*8*	*3*	*2*
C	26	2	1,314	381	*81*	*69*	*50*	*41*	*28*	*21*
D	26	None (Check)	1,541	608	*104*	*131*	*102*	*148*	*122*	*127*
E	21	3	1,186	282	*60*	*41*	*24*	*24*	*5*	*12*
Road A–E	Overlap	3–6	425	183	*30*	*30*	*2*	*13*	*0.9*	*1*
F	29	3	1,933	293	*72*	*61*	*26*	*27*	*11*	*12*
G	24	2	1,081	392	*56*	*32*	*6*	*17*	*9*	*14*
H[a]	1	1	347	168	*16*	*8*	*2*	*2*	*2*	*5*
I[b]	1	None (Check)	494	212			*91*	*97*	*101*	*89*

[a] Sprayed from ground, but all other sprayed plots treated from airplane.
[b] Unsprayed check plot for ground spraying treatment.

EFFECT ON BIRDS

Since it seems likely that birds would be affected, either by ingestion of poisoned insects or through reduction of their supply of invertebrate food, a thorough study was made of the bird population. This is the first recorded breeding bird census in the southeastern hammock-type forest. Censusing was accomplished on two 64-acre areas, sprayed and unsprayed, by the spot-mapping method of Williams (1936). This involved recording the occurrence of all birds on maps, fresh copies of which were used on each count. Observations were made while traversing the areas along marked lines 100 feet apart. Daily trips were made to each area during three periods: April 13–18 (before spraying), April 20–24 (after spraying), and again May 16–25. At the end of each period all records were transferred to species maps, and on the basis of the "territory concept" clusters of records were interpreted as indicating the presence of one breeding pair of birds for each cluster. Table 2 shows the population densities for both the sprayed and the check area, arranged by periods to show fluctuations in abundance.

A rather large initial difference in populations in the two areas, both as

to relative and total abundance of bird species, was noticed. The sprayed area, with 133 trees per acre, had 169 pairs of birds per 100 acres; whereas, the unsprayed area, with 210 trees per acre, was the poorer habitat with approximately 93 pairs per 100 acres. The ecological factors associated with this population difference would appear to be as follows:

	Sprayed Area	*Unsprayed Area*
Stocking:	133 trees per acre.	210 trees per acre.
Composition:	Less pine (5,220 board feet per acre).	More pine (15,060 board feet per acre).
	Less oaks.	More oaks.
	Less sweet gum and elm.	More sweet gum and elm.
	More palmetto.	Less palmetto.
Edge:	Areas adjacent to boundary wooded—28 per cent.	45 per cent.
	Areas adjacent to boundary open (Fields, ponds, 60-foot fire lanes)—72 per cent.	55 per cent.
Interior Openings:	Woods more open, due to past light selective cutting, hurricane kill of scattered pine and a few natural semi-open sloughs.	Woods less open. No cutting or hurricane damage.
Ground Cover:	More small cabbage palmetto.	More dwarf palmetto.
	More yaupon.	More cane thickets.
	More sawgrass.	
Topography:	Higher ground with less standing water.	Lower, flatter woods with poorer drainage.

After spraying no sick or dead birds were found on the DDT plots. It may be noted from an examination of Table 2 that there was no significant sudden change in the bird population after the spraying. The changes that did occur were gradual and seemed to be normal seasonal fluctuations in both sprayed and unsprayed plots. The percentage of increase in late nesters was greater in the unsprayed check plot (42.9 per cent) than in the sprayed (10.2 per cent); while the percentage of birds leaving was about the same in both areas. This might have been caused by the reduction of insect food by DDT. However, this is not in accordance with the pattern of effect of conspicuously damaging concentrations of DDT noted by Hotchkiss and Pough (1946) in Pennsylvania. There, a reduction of the bird population took place immediately after spraying five pounds of DDT per acre, with a gradual increase in density from then on. Furthermore, observations at Bull's Island showed that insect populations had recuperated considerably by the time of the last bird census, at which time the different rates of increase in bird populations on the two areas were noted. These different rates may have been the result of an earlier, greater saturation of population in the sprayed area, thus allowing for fewer late increases. On the other hand, they may have been due to differences in

habitat preference between the majority of early and late nestings. For instance, greater amounts of pine would favor late increases in pine warblers and deciduous growth would favor red-eyed vireos and gnatcatchers. All things considered, it appears that there was no significant difference in the population of birds resulting from the application of three pounds of DDT per acre.

environments. Green tree frogs (*Hyla cinerea cinerea*) started falling from the trees within two hours after spraying three pounds of DDT per acre. It is presumed that the earliest mortality was caused by direct contact with the spray. By the second and third days after spraying a considerable number of these little frogs was found dead or undergoing "DDT paralysis"; but the population apparently was not reduced

TABLE 2.—POPULATION OF BIRDS ON TWO WOODLAND AREAS BEFORE AND AFTER SPRAYING ONE, WITH THREE POUNDS OF DDT PER ACRE

	Sprayed Area (Plots A, B, and E)				Unsprayed Area (Plot J)			
	Pairs per species On 64 acres			Pairs per 100 acres	Pairs per species on 64 acres			Pairs per 100 acres
	Pre-spray 4/13–18	Post-spray 5/20–24	Post-spray 5/16–25	Post-spray 5/16–25	Pre-spray 4/13–18	Post-spray 4/20–24	Post-spray 5/16–25	Post-spray 5/16–25
Parula Warbler	17.0	18.5	18.5	29.0	5.0	6.5	6.5	10.0
Pine Warbler	15.5	16.5	15.0	23.5	5.0	9.5	9.5	15.0
Cardinal	14.5	15.5	15.0	23.5	7.0	9.5	10.0	15.5
Carolina Wren	13.0	14.0	14.0	22.0	9.0	10.0	10.5	16.5
Crested Flycatcher	6.5	6.5	7.0	11.0	2.5	3.0	3.0	4.5
White-eyed Vireo	4.5	5.0	6.5	10.0	3.0	3.0	4.0	6.0
Red-eyed Vireo	8.0	8.5	5.0	8.0	3.5	6.5	4.5	7.0
Yellow-throated Warbler	4.5	5.0	5.0	8.0	0.0	0.0	1.0	1.5
Chuck-wills-widow	3.0	3.0	4.0	6.0	1.0	1.0	1.0	1.5
Painted Bunting*	0.0	1.0	4.0	6.0	0.0	0.0	2.0	3.0
Blue-gray Gnatcatcher	0.0	1.0	3.0	4.5	0.0	1.0	4.5	7.0
Pileated Woodpecker	2.5	2.5	3.0	4.5	2.0	2.0	2.0	3.0
Red-bellied Woodpecker	2.0	2.0	2.0	3.0	0.0	0.0	0.0	0.0
Yellow-throated Vireo	2.0	2.0	2.0	3.0	1.0	1.0	0.5	1.0
Wood Duck	2.5	3.5	2.0	3.0	1.0	1.0	0.5	1.0
Wild Turkey**	2.0	2.0	1.0	1.5	1.0	1.0	1.0	1.5
Yellow-billed Cuckoo	0.0	0.0	1.0	1.5	0.0	0.0	0.0	0.0
Summer Tanager	0.0	0.5	0.5	1.0	1.0	0.0	0.0	0.0
White-eyed Towhee	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals***	98.5	108.0	108.5	169.0	42.0	56.0	60.0	93.0
Percentage of population change from pre-spraying level		+9.6	+10.2			+33.3	+42.9	

* Includes singing males in immature plumage.
** Wild turkey hens; gobblers also present.
*** Crows present but not included due to control program.

EFFECT ON OTHER FOREST VERTEBRATES

Observations on amphibians, reptiles, and fish were numerous and extensive, but no quantitative studies were made.

Amphibians. Two species of frogs were abundant in their respective forest

to a dangerously low level.

In the forest rainwater pools the southern leopard frog (*Rana pipiens sphenocephala*) was commonly affected by the spraying. Adults and larval forms died, particularly in those pools poorly protected by forest canopy. It is

not known to what extent the degree of kill was caused by direct contact or by ingesting poisoned insects, which were abundant on the surface of many pools. As with the tree frog, many leopard frogs were affected; but the distribution was spotty, and many forest pools appeared to have no affected frogs or insects.

Reptiles. The most abundant forest reptile was the chameleon (*Anolis carolinensis*). On 64 acres receiving three pounds of DDT per acre only two chameleons were found affected during the regular strip censusing; one of these was dead and the other experiencing tremors and partial paralysis, from which it recovered after a day and a half in the laboratory. One common water snake (*Natrix sipedon sipedon*) was found 26 hours after spraying, going through mild convulsions and unable to progress; its ultimate fate was not determined. One black snake (*Coluber constrictor constrictor*) was picked up 72 hours after spraying, and was almost completely paralyzed, remaining on its back most of the time. It recovered after several days in the laboratory and was released. Cottonmouth moccasins (*Agkistrodon piscivorus*) which, like the black snakes, were common before and after spraying, were apparently unaffected. This applied also to the less abundant chicken snake (*Elaphe quadrivittata*). While data on amphibians and reptiles were limited, airplane spraying on a fairly closed canopy appeared to have no serious effect on these animals.

Fish. The effect on fish was minor and spotty, with practically no damage observed in rain pools protected by forest canopy. In an open fire-lane pool, on the edge of Plot A, presumably where a large percentage of the full spray of three pounds of DDT per acre reached the water surface, mosquito fish (*Gambusia holbrooki*) were found dead and dying one day after spraying in a somewhat similar exposed situation, a brackish water pool receiving two pounds of DDT per acre, many broad killifish (*Cyprinodon variegatus*) were killed. No attempt was made to determine the proportion of dying fish in total populations.

Mammals. The introduced fox squirrel (*Sciurus niger*), which, by reason of its arboreal life, might be considered susceptible to DDT spraying, was censused before and after spraying, daily observations being spot-mapped in the same manner as were birds. Our observations on the two 64-acre plots revealed a population of one squirrel to six acres. From the limited data secured, it appeared that DDT spraying had no effect on fox squirrels.

Small rodents known to inhabit the woods were Cotton mouse (*Peromyscus gossypinus*), Swamp rice rat (*Oryzomys palustris*), and Norway rat (*Rattus norvegicus*). None was found sick or dead.

Other mammals present were the raccoon (*Procyon lotor*) and the white-tailed deer (*Odocoileus virginianus*). No reaction to DDT was observed for them.

EFFECT ON SALT MARSH ANIMALS

A portion of Plot G included the upper zone of coastal salt marsh that lies next to the uplands. This marsh is dominated by short salt marsh cordgrass (*Spartina alterniflora*), glasswort (*Salicornia* spp.), and needle rush

PLATE 1.—*A*. Typical understory of cabbage palmetto on Bull's Island. *B*. Salt marsh on Bull's Island and quadrat of sheet metal used to imprison crabs.

(*Juncus roemerianus*), and is covered by only the highest tides.

Prior to airplane spraying with two pounds of DDT per acre, twelve yard-square quadrats were established throughout the marsh, and counts were made of the larger invertebrates, employing a portable sheet-metal enclosure to prevent animal escape from the quadrats during the actual counting. Animals tallied were released unharmed, and the post-spraying quadrats were established in the vicinity but not on the same yard-square spots as the pre-spraying quadrats.

TABLE 3.—POPULATION OF LARGER INVERTEBRATES ON TWELVE SQUARE-YARD PLOTS LOCATED IN THREE ACRES OF UPPER SALT MARSH, BEFORE AND AFTER SPRAYING WITH TWO POUNDS OF DDT PER ACRE[a]

Species	Pre-spraying, 4/20/46			Post-spraying, 4/24/46[b]			Post-spraying, 5/16/46			Effect on Population
	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	
Fiddler Crabs *Uca minax* *Uca pugnax* *Uca pugilator* *Sesarma cinerea*	264	13 (5%)	277	28[c]	119 (81%)	147	3	Numerous fragmented remains		Practically total kill of fiddler crabs
Snail *Littorina irrorata*	242	3 (1%)	245	265	3 (1%)	268	204	6 (3%)	210	No significant change
Snail *Melampus lineatus*	37	0	37	14	0	14	156	6 (4%)	162	No significant change
Mussel *Modiolus demissus plicatula*	54	3[d] (5%)	57	39	0	39	77	10[d] (11%)	87	No significant change

[a] Each square-yard plot had same general location and vegetative type on successive examinations, but was purposely not placed on the exact spots of preceding examinations.
[b] Sprayed by airplane on 4/22/46.
[c] Most of the living fiddler crabs were obviously affected by the DDT, and presumably dying.
[d] Predominantly old, dead shell, not the result of DDT spraying.

Airplane spraying presumably resulted in a large percentage of DDT reaching the marsh level. By reason of their feeding on organic matter in suspension or deposited on the surface of marsh plants and mud, these invertebrates might be expected to be particularly vulnerable to DDT. As shown in Table 3, snails and mussels were undisturbed by DDT, but the effect on fiddler crabs was immediate and severe. Although no check plots were established, general observations on adjacent unsprayed marsh revealed stable populations there after spraying.

One day after spraying, 81 per cent of the crabs were found dead, and more were presumably dead or dying in the deepest burrows that were not excavated. Of the few living crabs present, most were slow-moving and obviously affected by DDT. Moreover, the twenty-eight living crabs found the day after spraying were only 10 per cent of the 264 found living on 12 similar quadrats before spraying. The three live ones found about one month later were only one per cent of the original 264.

The ultimate kill of fiddler crabs on this type of salt marsh, which receives little daily flushing, can be expected to approach totality. This is a serious condition, when one considers what widespread salt-marsh spraying might

do to this important food item in the diet of fishes, the clapper rail, shorebirds, and the coastal raccoon.

SUMMARY

Observations were carried on at Bull's Island, Charleston County, South Carolina in the spring of 1946 to determine the effect of airplane spraying to control ticks.

Observations on animal populations were made in five plots including open salt-marsh and hammock type forest. Three pounds of DDT per acre, in solvents of xylol or pine oil, diluted with water, was sprayed above the tree tops in the forest plots. The highest rate of DDT deposit recorded at ground level in the forest was .91 of a pound; but the average deposition at 59 random sampling stations was only .14 of a pound. Under such conditions of deposit ticks were progressively reduced on sprayed areas, reaching 85 per cent control six weeks after spraying. The ticks continued their normal trend of seasonal increase on untreated forest plots. Insects were greatly affected, the degree depending chiefly on the protection afforded by the forest canopy and understory of shrubs.

On 64 acres of forest sprayed at the rate of three pounds of DDT per acre, there was a bird population (excluding crows) of 98.5 pairs before, and 108.5 pairs after treatment, a 10.2 per cent increase; while on 64 acres of unsprayed forest, there were 42 pairs of birds before, and 60 pairs after spraying, a 19 per cent increase. DDT treatment had no apparent effect on nesting birds. The differential increase in nesting during April and May was attributable to initial differences in nesting populations and to a differential in ecological requirements of later nesters.

Amphibians were commonly killed by the treatment but many were unaffected. Reptiles and fish apparently were affected to a lesser degree than were amphibians. No reaction to DDT was observed for fox squirrels and other mammals.

On salt marsh adjacent to forest, an aerial application of two pounds of DDT per acre resulted in practically complete elimination of the abundant fiddler crabs, but had no immediate effect on snails and mussels.

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EFFECTS OF DDT ON BIRD POPULATION OF SCRUB FOREST

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A number of studies have been made by the U. S. Fish and Wildlife Service to determine the effects of DDT on vertebrate life. The work has covered a variety of situations and several dosage rates have been used. As far as birds are concerned, the results have shown that DDT applied to forest areas at a rate of one pound per acre has but slight effect (Hotchkiss and Pough, 1946; Kendeigh, 1947). Repeated applications of small dosages of DDT (0.1 pound per acre) as practiced in malaria control, have been studied for effects on birds by Erickson (1947). He failed to find any measurable effects following 17 weekly applications. Following a two-pound-per-acre treatment of a lowland woods, Stewart, et al. (1946) could find no conclusive evidence of mortality in a nesting population, but some changes in habits appeared to have resulted. An experimental treatment of a portion of dense second-growth hardwood forest with five pounds of DDT to the acre was found by Hotchkiss and Pough (1946) to cause a significant reduction in the bird populations.

It is becoming increasingly apparent that control of forest insect pests by aerial dispersion of DDT will be practical under some conditions. In order that such control work can be done with a minimum adverse effect on beneficial animal life, the Forest Insect Division (Bureau of Entomology and Plant Quarantine) and the Fish and Wildlife Service are continuing a program of cooperative studies. Effects of DDT at different dosage rates per acre are being determined for vertebrates and invertebrates in both aquatic and terrestrial habitats.

A determination of the critical dosage level and conditions of application which create definite hazards to wildlife is urgently needed. The present study details the effects on a bird population of a five-pound-per-acre application where the nature of the cover was such that little "screening out" of the spray occurred. The absence of a canopy, and resultant deposition of a large percentage of the spray at ground level, also approximated conditions that might be met in comparable control attempts in some agricultural situations.

The area chosen for the test is a 90-acre tract located on the Beltsville Agricultural Research Center, two miles west of the Patuxent Research Refuge on the Coastal Plain of Maryland. The area was burned over in 1942 and is now covered with a scrub and sapling growth. Numerous dead pine and oak trees of the former forest are still standing. The commonest woody plants in the sprayed area, all in the form of saplings, sprouts, or shrubs, are sweet gum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), black gum(*Nyssa sylvatica*), and dwarf sumac (*Rhus copallina*). Large-toothed aspen (*Populus grandidentata*), willow oak (*Quercus phellos*), white oak (*Q. alba*), tuliptree

(*Liriodendron tulipifera*), pin oak (*Quercus palustris*), and American holly (*Ilex opaca*) are also widespread. A 30-acre study area was set up in the center of this sprayed unit.

A check area in the same burned area was located about a half mile away. Due to the rolling nature of the land, moist pockets alternated with drier areas, leaving no 30-acre tracts of entirely uniform vegetation. However, the check area finally chosen, differed only slightly from the sprayed area. It had a much smaller number of standing dead trees, and consequently an almost complete absence of house wrens, one of the most common birds in the sprayed area.

The check area included four acres of low ground on which the principal plants were swamp magnolia (*Magnolia glauca*), cinnamon fern (*Osmunda cinnamomea*), black gum, highbush blueberry (*Vaccinium corymbosum*), and chokeberry (*Aronia* sp.). The remainder of the area, uniform as far as bird distribution was concerned, was composed of two minor vegetative types: a dry section occupying the higher land, where chestnut oak (*Quercus montana*), scarlet oak (*Q. coccinea*), and dryland blueberry (*Vaccinium vacillans*) were the most abundant plants; and a slightly damper area characterized by white oak, black gum, large-toothed aspen, and smooth sumac (*Rhus glabra*). The latter type was most similar to the sprayed area.

TABLE 1.—COMPARISON OF POPULATIONS OF 12 COMMONEST SPECIES IN SPRAYED AND CHECK AREAS BEFORE TREATMENT

Species	Number of Pairs	
	Sprayed	Check
Prairie warbler (*Dendroica discolor*)	15.0	26.0
Maryland yellow-throat (*Geothlypis trichas*)	24.0	14.0
Red-eyed towhee (*Pipilo erythrophthalmus*)	17.0	14.0
House wren (*Troglodytes aedon*)	15.0	1.0
Yellow-breasted chat (*Icteria virens*)	4.2	5.0
Field sparrow (*Spizella pusilla*)	2.0	3.0
White-eyed vireo (*Vireo griseus*)	1.7	2.0
Eastern goldfinch (*Spinus tristis*)	0.5	3.0
Eastern bluebird (*Sialia sialis*)	2.0	1.0
Brown trasher (*Toxostoma rufum*)	1.5	1.3
Eastern wood pewee (*Contopus virens*)	1.5	1.0
Indigo bunting (*Passerina cyanea*)	0.8	1.5

Censusing was started on June 24, 1947, in the sprayed area, and the day following in the check area. Three census trips in the sprayed area on April 14 and May 14 in connection with a previous study, also helped to complete the picture of early nesting birds such as woodpeckers and chickadees. The census work was done between 4:40 and 9:10 a.m., standard time, except for three trips which started an hour before sunset and continued until whip-poor-wills (*Caprimulgus vociferus*) were in full song. A total of 79 man-hours was spent on actual censusing; and 38 additional hours were spent searching for nests and sick birds. In the sprayed area 17 census

trips were made before the DDT application, and 28 following. In the check area 11 were made before the date of spraying, and 15 thereafter.

Censuses were conducted in a manner similar to that of Williams (1936).

Table 1 compares the populations of the 12 commonest bird species in the two areas. The next 14 species in order of abundance were all present in both areas, but only in very small numbers (one pair or less in each area). The number of pairs of each species actually represents the number of occupied territories.

The spray solution (one pound of DDT dissolved in 1.2 quarts of a refined solvent, and made up with fuel oil to one gallon of solution) was applied by plane at the rate of five pounds of DDT in 4 gallons of liquid per acre, beginning at 6:00 a.m. on July 3.

Effects on insects were immediate and very pronounced, but no unusual activity among birds was noted until 12 hours after spraying, when a male scarlet tanager (*Piranga olivacea*) was seen flying back and forth over a large area catching insects in flight; a similar observation of this atypical behavior of a tanager was made in a previous DDT study on the Patuxent Research Refuge. Although no sick birds were observed on the day of spraying, an evening census conducted on both areas 12 hours after the application, showed a definite decline in the numbers of yellow-throats and prairie warblers observed in the treated area.

Regular censuses were resumed at 5:25 on the morning following spraying. By 8 o'clock it was apparent that certain species of birds had been seriously affected as a result of feeding on

TABLE 2.—OBSERVATIONS ON AFFECTED BIRDS AFTER DDT TREATMENT AT 5 POUNDS PER ACRE

Elapsed time since spraying		Observation
Hours	Minutes	
24	40	First and only sick chat observed; could fly, but appeared weak, flapped its wings while perched, opened its beak frequently, and called occasionally.
25	40	Adult male yellow-throat found with tremors; movements uncoordinated; could hardly fly, but kept fluttering wings while perched.
26	10	Sick field sparrow seen; could fly and perch only with difficulty.
26	10	Effect of DDT becoming quite noticeable; very little singing except by towhees, which gave no appearance of being affected.
28	0	Two prairie warblers recently out of nest calling for food; watched for 15 minutes; and at intervals for over an hour; no sign of parents. Slight trembling of wings may not have been due to DDT poisoning.
28	15	Sick immature prairie warbler caught by hand; muscular tremors very noticeable.
28	30	Flicker (*Colaptes auritus*) feeding small young in nest. Young not heard on subsequent days.
28	50	House wren actively building nest all morning; not seen after this time.
29	0	Young field sparrow with slight tremors had difficulty keeping eyes open; caught by hand.
29 to 34	45 to 20	Another sick field sparrow seen.
36	40	Another prairie warbler seen with tremors; could not be caught by hand, so was shot for examination.

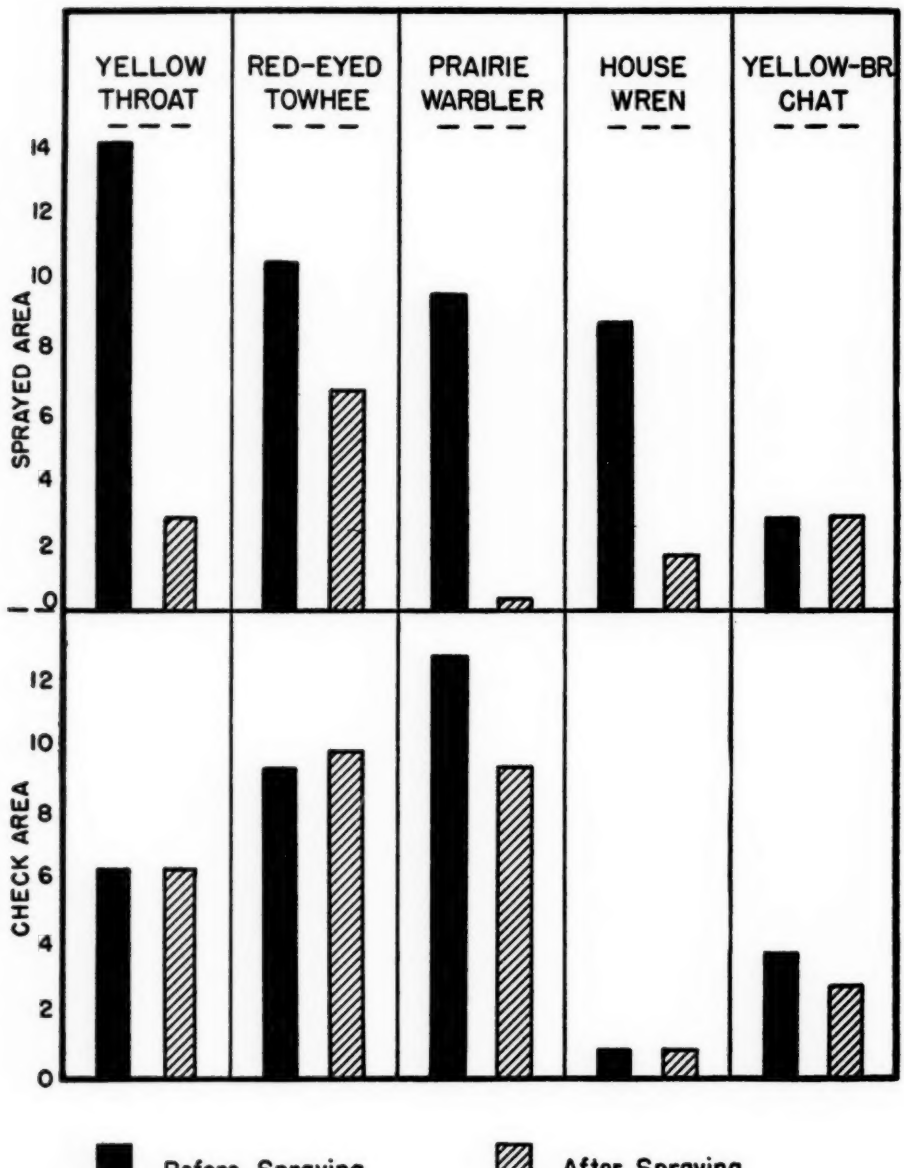

FIG. 1.—Average number of birds on check and treatment area before and after application of DDT in oil at the rate of 5 lbs. actual DDT per acre.

poisoned insects. In order to account for as many victims as possible, additional help was summoned, and the sprayed area was systematically covered between 9 and 11 a.m. Observations by single observers continued periodically until dark. Notes of particular interest are included in Table 2.

Although the population continued to decline after the close of this second day, no other sick birds were found. Due to the dense growth of shrubs and young trees, it is not surprising that no dead birds were located.

Figure 1 gives a summary of the toxic effect on the five commonest species. The vertical scale gives the average number of individuals recorded in the sprayed area (above) and the check area (below). The average number of birds recorded before spraying (as shown by the heavy, black bar) was obtained from the 13 trips taken on June 26 and 27. The average number after spraying (shown by the hatched bar) is the average of all early morning trips from July 6 through July 17. Census figures for July 3, 4, and 5, the period immediately following spraying, were omitted due to the rapid changes in population.

Populations in the check area were very similar before and after spraying (Figure 1). The only appreciable drop occurred in the prairie warbler, and this is accounted for by the waning of the song season and departure of birds from their territories as young birds left the nest. In the sprayed area, on the other hand, very noticeable drops are noted in the first four species. The numbers of yellow-throats declined by 63 per cent in the first 24 hours, then dropped gradually for the remainder of the study, for a total decrease of 79 per cent. The red-eyed towhee showed a comparatively slight drop of 35 per cent, possibly due in part to its habit of scratching in the leaves and feeding on insect material which had been at least partly protected from the spray. The prairie warbler decreased 64 per cent during the first day, and by the end of 48 hours was down to seven per cent of the former population. After seven days, however, there was a slight increase, probably due to wandering of birds from nearby regions; the average population from July 6 to July 17 showed an 80 per cent drop over and above the decline in the check area. The house wren population fell 59 per cent the first day, then dropped gradually for six succeeding days. After that, as in the prairie warbler, there was a very slight increase. The total drop for the species was 80 per cent.

Of the five commonest breeding species, representing 77 per cent of the total population, only the yellow-breasted chat showed no decrease—and this in spite of the observation of one sick bird. All other species were present in too small numbers (two pairs or fewer per area) to allow any conclusions to be drawn, but the total drop for the five mentioned above, was 65 per cent. The observations of sick birds, and desertion of fledglings by their parents suggest that the decrease in population was due largely to poisoning rather than to a general exodus of birds from the entire sprayed area.

SUMMARY

An oil spray of DDT was applied at the rate of five pounds per acre to a 90-acre tract of 5-year-old scrub and sapling growth at Beltsville, Maryland. Bird population studies were carried on in a 30-acre plot at the center of the sprayed area, and in a 30-acre check area of the same habitat one-half mile away. Of the five commonest species in the sprayed area, the Maryland yellow-throat, prairie warbler, and house wren

were reduced 80 per cent, and the red-eyed towhee was apparently reduced 35 per cent; while no appreciable change in the numbers of yellow-breasted chats was noted. The total decrease for the five commonest species, which represented 77 per cent of the original population, was 65 per cent.

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ALLIGATOR MANAGEMENT OF THE SABINE NATIONAL WILDLIFE REFUGE

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INTRODUCTION

Only thirty years ago the land in southwest Louisiana that now comprises the Sabine National Wildlife Refuge was undeveloped coastal marsh. Except for several marginal bayous, the marsh offered few means of ingress and was little frequented by man; large portions were virtually unexplored.

Originally it was a haven for myriads of migratory waterfowl and supported a large and varied population of indigenous wildlife. Among species best adapted to the habitat was the alligator (*Alligator mississippiensis*). So numerous were these reptiles that old hunters speak of having seen their eyes, in the glare of a headlight, shining on the bayou waters as thickly as the stars overhead. In the spring the bellow of the males was one of the most characteristic sounds of the marsh.

In the middle 1920's the area was opened up primarily for trapping furbearing animals. Canals were dug through the remote areas, trappers camps built at strategic intervals, and systematic exploitation of the natural resources began. Fur was trapped in the winter, and alligators were hunted during the rest of the year.

In normal years the trapping was never intensive enough to deplete the furbearers seriously. The same, however, cannot be said of alligator hunting. During dry periods the marsh was

burned in the spring and summer to facilitate travel and to permit hunting over a greater territory. At times, a marsh buggy was employed to break trails and to provide transportation into interior areas. Every year, regardless of weather, the canals were hunted clean by means of boat and headlight. No species so vulnerable could withstand this exploitation, and, within a relatively short period, the alligators were far reduced.

Establishment of the refuge in 1935 prevented complete extinction of the alligator. Despite the retention of hunting and trapping rights for 10 years by former owners, the hunting of alligators was diminished so that the species, at the end of the period, was no longer threatened.

Indiscriminate burning was one of the most significant factors in destruction of the alligator. Under Government control, such burning was prohibited, the rank growth of tall, dense vegetation, characteristic of most of the marsh, effectively limited the hunting. Along the canals and bayous intensive hunting continued, but areas of impenetrable marsh remained as sanctuaries.

The alligator population was beginning to recover in 1945 when the hunting rights of former owners expired. On certain favorable areas alligators, mostly of younger age classes, were abundant. In contrast, the species is becoming uncommon on adjacent marshes, and others in southwestern Louisiana.

A program of investigation and hunting was started during the summer of 1946 to obtain a better understanding of the population on the refuge, since previous knowledge had been scanty. Available information had been obtained by observations in areas accessible by boat and from local residents with hunting experience on the marsh; records from the interior were few. More information was needed because the alligator is important from the standpoint of predation, and is valuable as a source of leather.

The Sabine Refuge includes 142,000 acres, and the alligator population is widely scattered. It seemed feasible to gather a large number of data in limited time by hunting. Experience from kill and from hunting activities together with observations would serve to provide a fairly complete picture of the population and of its effect on other wildlife.

The major points for consideration were:

(a) size of the population and its distribution, (b) the influence of alligators on other wildlife obtained principally through a study of its food habits, and (c) breeding, nesting and correlated data.

The hunters employed were asked to cover as much territory as possible to obtain some idea of conditions throughout the refuge area open to hunting. Unfortunately high water early in the season restricted the hunting to open water accessible by boats. Later some marsh hunting was possible, and a fair sample of the marsh was covered. A marsh buggy was available, and several trips were made into areas inaccessible on foot. The data for one season presented here are indicative and conclusions may be modified by future research.

REMOVAL

For hunting the refuge was divided into seven essentially comparable units as to area of open water and extent of known alligator marsh. These comprised roughly three-fourths of the entire refuge. The remaining area was closed to hunting. On some areas the population was too small to withstand hunting, and on a strip of marsh adjacent to refuge headquarters and State Highway No. 104, the alligators were protected for aesthetic purposes.

Because of water conditions, hunting was conducted during two separate periods. The first, of about one month, began on June 3, 1946. At the end, the number of alligators in and adjacent to the canals and bayous was so small, as a result of the kill and their general retreat into remote marsh, that hunting became unprofitable.

The second period began September 1 when water levels had receded so that hunting the marsh on foot was possible. Hunting then was on a reduced scale, as few hunters have the stamina or inclination to tackle the dense marsh vegetation in the heat of summer. Hunting lasted for three weeks, being terminated by heavy rains which reflooded the marsh.

Shortly before the second period there was a noticeable return of alligators into the open waters, until, by early September, they were present in about half of the original numbers. To obtain data on the more strictly "marsh" population, work was restricted to pole hunting in the marsh.

The movements from open water to the marsh late in June and back to open water by early September are correlated in part with water temperatures. During the summer, the open water becomes excessively hot, and the alligators retreat to underground burrows or deep "wells" back in the marsh where the tall vegetation offers some protection against heat of the sun. This summer migration, apparently typical on the Sabine Refuge, is evidently the reverse of normal movements on natural areas of brackish tidal marsh. On the latter, alligators tend to remain in the marsh until the summer and then concentrate in the bayous.

In natural tidal marsh, the high rate of summer evaporation, plus normally low tides, produce correspondingly low water levels with high temperatures and periods of stagnation. The alligators consequently move into the bayous cooled and freshened by tidal action.

On the Sabine Refuge, natural conditions have been altered by the canal system. Canal spoil banks prevent drainage and maintain more stable water levels, improving the marsh as a summer habitat. The canals, however, somewhat counteract the cooling action of the tides. Tidal inlets are few in number whereas the canal system is so extensive that, in total area, it comprises a large body of inland water. In this water system, any cooling effect of the tides is so reduced as to have no perceptible influence by the time it reaches the interior of the refuge. As a result, the canal waters will attain extremely high temperatures during the hot months. These conditions strongly indicate that water temperature may be a determining factor in the seasonal movement of alligators.

The total number of alligators taken was 1,075. A break-down, on the basis

of size classification, is given in Table 1. Only two permittees were able to kill their entire quota of alligators. The fact that others were unable to do so is attributed to unfavorable conditions rather than a scarcity of alligators.

TABLE 1.—SIZE CLASSIFICATION OF ALLIGATORS KILLED ON SABINE MARSH, 1946

Length in feet	Number
3	324
4	399
5	158
6	67
7	79
8	33
9	7
10	7
11	0
12	1
Total	1,075

Many observations indicate that there is a corresponding decrease in the total number of alligators with increase in length. This seems to hold true for the entire range of sizes, though it is doubtful that the size gradient is actually proportionate. This size variation is evident from the kill records, though these do not actually portray the number of alligators in each size class; for instance, fewer 3-foot animals were killed than 4-foot ones. This is because some hunters arbitrarily set 4 feet as a minimum and did not kill smaller than borderline individuals whose size could not be judged accurately.

The method of hunting also determined the size of those killed. Those taken in open water from a boat were definitely smaller than others killed by pole hunting in the marsh. This results from the habits of the animal. Young alligators tend to concentrate in the vicinity of open water while mature individuals, particularly breeding females, are more apt to confine their activities to a definite territory and may not appear in open water unless such water is in or bordering to their territory.

In both methods of hunting, however, there were fewer alligators killed of the larger size classes.

ALLIGATOR INVESTIGATION

SIZE AND DISTRIBUTION OF THE POPULATION

The hunt and coincident observations failed to provide any single factor upon which to base a population estimate. It was therefore necessary to combined all the abundance data accumulated in calculating the actual size of the population. Factors useful to indicate abundance included:

a. The number killed on the different units and the estimated percentage of removal determined by subsequent field observations.
b. The estimated numbers in unhunted territory, based on present knowledge of distribution and areas of concentration.
c. The ratio of sexually mature adults to juveniles.
d. Hunters' reports of individuals observed, particularly in areas not visited by refuge personnel during the investigation.
e. The proportions of individuals in different size classes.

The last factor was significant because our hunting regulations prohibited the killing of alligators less than 3 feet in length. Consequently, the kill provided no index to the number of

small animals. A fair indication of the population of young was obtained by observations along waterways and adjacent marsh throughout the refuge; these were particularly significant if made at night when the alligators were concentrated in open water and could be easily spotted with a headlight. The night-time counts showed that most of the total population consisted of young.

Considering all data, the refuge has an estimated total of 15,000 alligators. This figure includes an estimate of the hatch of young during 1946 but excludes the 1,075 removed during the hunt. Approximately two-thirds of the population comprises specimens less than 3 feet in length; in terms of harvestable animals (3 feet or over), the refuge supports only about 5,000.

Practically all the refuge is alligator range, but the animals are not evenly dispersed over the area, tending to concentrate in more favorable habitat.

Alligators, particularly the young, tend to congregate where open water is available. They are most common along the canal and bayous and about the lakes. The largest concentration is in one area of deep marsh where ponds and lakes, comprising hundreds of acres, have developed following disintegration of the marsh vegetation.

On the western end of the refuge the remnant of a former large concentration still exists. This developed following a deep peat burn during a drought of the early 1920's. Ponds thus resulting extended northward from a canal for 3 miles. In the past thousands of alligators were killed in this strip of ponds, resulting in near extermination. During recent years, the population has recovered somewhat, but most of the old habitat is gone as marsh vegetation has invaded virtually all of the old burn.

Comparatively large areas of the marsh, on the other hand, are either unsuited or of limited usage as alligator habitat. Such areas including ridgelands and tracks of dense, continuous vegetation, unbroken by bodies of open water support few or no alligators. Ridgelands, however, may be of seasonal importance. During the nesting season, if the water level in the marsh is abnormally high, mature females tend to utilize the wet margins of ridges as nesting sites.

INFLUENCE ON OTHER WILDLIFE

The hunt offered an excellent opportunity to collect alligator stomachs, to determine dietary predilections. The alligator is a predator and study of its food habits is one of the best means to learn its influence on other wildlife.

All hunters were required to preserve stomachs from the animals killed. Every 2 or 3 days all camps were visited and the stomachs collected. Occasional fresh stomachs were examined in the field, but this practice was too time consuming to be used extensively.

Alligators make little attempt to chew their food. Small prey is swallowed whole and larger animals are crushed or torn and swallowed in pieces. Consequently, identification was simplified, if digestion was not far advanced.

In all 318 stomachs were analyzed, or slightly less than one-third of the animals killed, and all but 13 (4 per cent), contained food.

Since all stomachs were taken during the summer, it was impossible to deter-

mine seasonal variations or preferences in the diet.

Alligators seem to be almost strictly carnivorous. Plant material appeared frequently in the stomachs, but was not considered as food. About one-third of the stomachs contained root fragments. These were found particularly in the larger animals. Presumably the roots were consumed during burrowing activities. The larger root pieces evidently are slow to leave the stomach for these were often worn smooth and had become exceedingly hard. The only other plant inclusions were leaf and stem fragments of pennywort (*Hydrocotyle*) and alligator-weed (*Alternanthera*), found in 3 stomachs. These latter probably were accidental items picked up in canals when feeding on crayfish or other aquatic animals. The types of animal food are presented in Table 2.

TABLE 2.—ANIMAL FOOD OF ALLIGATORS

Food	Number Eaten	Percentage Occurrence
Crustaceans	824	*85.2*
Reptiles	94	*25.2*
Mammals	67	*20.3*
Fishes	193	*13.5*
Birds	35	*11.0*
Insects	566	*30.5*
Amphibians	3	*.9*
Unidentified Vertebrates	2	*.7*
Miscellaneous	14	*4.4*

Crustaceans. From the numbers eaten and the number of stomachs in which they occurred, crustaceans may be considered the most important food. They were eaten extensively by alligators of all sizes, but were of pronounced importance to the smaller alligators, and made the bulk of their food. In alligators of larger size, vertebrate foods preponderate.

Crayfish (*Cambarus*) were by far the most important of the crustaceans consumed. A total of 797 was found in 264 stomachs. The largest number in any one stomach was 48, all of which were small and immature.

Crabs (*Callinectes*) were of minor importance, only 17 individuals occurring in 15 stomachs. Considering the abundance of crabs in waters of the refuge, their actual importance as food may not be correctly reflected in the stomach material. This is further indicated by 17 stomachs collected on the refuge in 1941 and analyzed at the Patuxent Research Laboratory. The crabs in the latter comprised 10 per cent of all crustaceans eaten. Water conditions during the hunting in 1946 may have been responsible for the small number of crabs taken. Most of the alligators were killed when water levels were high and the water was only faintly brackish. Fresh water may inhibit the activity of crabs to such an extent that their availability as a food becomes reduced.

Ten fresh-water shrimps (*Palaemonetes*) were found in 7 stomachs. These are insignificant as a food considering their small size and infrequent occurrence.

Reptiles. Snakes and turtles were an important source of food. The former were more frequent, 61 individuals in 56 stomachs. The common water snake (*Natrix*) predominated, and 18 could be identified as of this genus. Others recognizable were 3 cottonmouth moccasins (*Agkistrodon*) and one garter snake (*Thamnophis*). Most of the turtles eaten were mud turtles (*Kinosternon*);

altogether, 31 turtles were found in 28 stomachs.

Two records of cannibalism were noted. A complete specimen of young alligator, about 18 inches long, was recovered from one stomach, and remains of the toes and foot of a larger one in another. The material of the second case probably represents carrion.

Mammals. Muskrats (*Ondatra*) are the most abundant and the most readily available of all local mammals and provide the most important mammal food. A total of 59 were present in the stomachs. It was expected that predation on young muskrats would be particularly severe, but such was not the case as only 10 per cent of those eaten were recognized as young.

One reason for the study of food habits was to determine the influence of the alligator upon muskrat population. The latter is a furbearer of considerable economic importance in this coastal marsh and the alligator is popularly considered to be one of the limiting factors in muskrat production. This belief was not confirmed by our study for the Sabine Refuge. Muskrats were found in 55 stomachs, or 17.3 per cent of those examined, a frequency of occurrence insufficient to warrant condemning the reptile for its depredations. Muskrats are not important as prey because most of the alligators inhabit marsh that is not muskrat habitat or marsh areas "eaten out" by muskrats and no longer productive of these furbearers.

Where alligators occur on good muskrat marsh more predation may be expected. O'Neil (1943), on State-owned marshes, found muskrats in 46 per cent of 325 alligator stomachs.

Predation on muskrats of the Sabine Refuge conceivably would actually reduce the population only during extreme drought, when muskrats must abandon their usual marsh habitat and concentrate along the bayous and other available waters in alligator habitat. Then they would be extremely vulnerable and the alligators could take a terrific toll. Under drought conditions, however, losses might be expected with or without alligator predation as dwindling food supplies, intra-specific strife, disease and parasitism, and increased predation from all sources would tend to reduce the population to a level commensurate with the carrying capacity of the remaining environment.

In the present study, other mammals were insignificant as food. Raccoons (*Procyon*) occurred in 4 stomachs and mink (*Mustela*) twice. There were 2 unidentified inclusions of mammal hair.

Late in our study the method of collecting stomachs was seen to have a definite shortcoming. Hunters were not asked to tag the stomachs with data on the length and sex of alligators killed, hence we did not obtain a correlation between these factors and food preferences. The evidence gathered, however, points to a definite relationship between alligator size and the type of food eaten. The incidence of vertebrate food becomes greater with increase in size of the alligators, and the proportion of crustacean and other invertebrate foods diminishes. We obtained length measurements with 88 stomachs, which indicate this trend. This indication was also supported during the analysis of the unclassified stomachs.

So far as mammal foods are concerned, the dividing line between large

and small alligators is at about the 5-foot length. Of the 88 stomachs with length data, all those containing mammals with one exception, were from animals 5 feet or more in length. The exception was from a 4-foot alligator with a trace of raccoon fur.

The same relationship between size and mammalian foods was noted by O'Neil. Muskrats were more important as food where his investigation was made, but were not found in specimens less than 5 feet long.

Fishes. As a major food source fishes ranked fairly high, although their importance may be more accurately judged by the percentage of stomachs in which they occurred rather than by the number of individuals taken. Most of the fish were minnows, so that the volume of food represented is small. There were 74 minnows, nearly one-third of all fish eaten, in one stomach.

The fishes identified were as follows:

162 minnows
8 sun perch (Centrarchidae)
5 catfish
5 bowfin (*Amia calva*)
1 black bass
1 mullet (Mugilidae)
11 unindentified

The Sabine marsh contains an abundance of fishes which probably become more important as food during low water than was the case in the present study. Various minnows, especially top-minnows, are plentiful and widely distributed. The open ponds, canals, and bayous, and even the marsh water, support tremendous numbers of several species of sun perch and of the bowfin (*Amia calva*), locally known as choupique; both the perches and bowfin are known to comprise a considerable part of the alligator diet.

Strangely, no gar fish (*Strongylura*) appeared in any stomachs, although this fish is so abundant in the refuge waters as to be a nuisance.

Birds. There was more difficulty in identification of birds than any other class of food. These birds usually were represented by indigestible remains and could not be easily identified because of the lack of comparative material. Of the 35 birds eaten, the following identifications were made:

7 boat-tail grackles
3 purple gallinules
2 least bitterns
1 rail (Louisiana clapper?)
1 snowy egret
21 unidentified

Boat-tail grackles were the most common and probably several of the unidentified birds were the same species. This take of grackles is to be expected, as grackles are more numerous than any other bird species in the haunts of the alligator.

The purple gallinules comprised one adult, one young in the "down" stage, and one unhatched bird recovered complete with egg shell. The rail also was newly hatched and assumed to be a Louiaiana clapper, the most common species nesting locally. One other baby bird (unidentified) appeared among the food items. All the others, as far as could be ascertained, were either adults or fully feathered.

Insects. Second to the crustaceans were insects in number consumed and percentage of occurrence, but their small individual size reduces their importance as food. They are perhaps of great-

est value to young alligators. A variety of insects was eaten, the most important being aquatic beetles and their larvae. Of the 566 insects recorded, 452 were water tigers, the aquatic larvae of Dytiscid beetles. These were found in 33 stomachs, usually only a few specimens in each. In 2 stomachs they formed practically the entire contents, 210 larvae in one and 127 in the other.

In general, it appeared that insects were consumed in numbers and variety according to abundance and availability. The 566 insects included:

520 Coleoptera
- 452 water tigers (larval Dytiscidae)
- 51 aquatic beetles (adult Dytiscidae)
- 11 May beetles (*Phyllophaga*)
- 5 ground beetles (Carabidae)
- 1 unidentified beetle

39 Hemiptera
- 31 water bugs (*Belostoma*)
- 6 giant water bugs (*Lethocerus*)
- 2 water scorpions (*Ranatra*)
- 3 Diptera: aquatic larvae (Tabanidae)
- 3 Orthoptera: grasshoppers (Locustidae)

Amphibia. For some unknown reason amphibians were inconspicuous in the diet. Only 3 frogs (*Rana*) were found in stomachs, yet they are abundant throughout the habitat. We have often seen frogs at night sitting in vegetation bordering the waterways and within 2 or 3 feet of one or more alligators.

Miscellaneous. Several additional items appeared, though so infrequently as to have little dietary significance. These items consisted of 7 mollusks (Gastropoda), 6 spiders, and one earthworm.

Conclusions. The alligator is almost strictly carnivorous, and, to a degree, an important predator upon certain forms of wildlife. Its diet includes about every type of animal of edible size found in the environment. There seem to be no pronounced selectivity in food items (possible exceptions are gar fish and frogs). The alligator evidently takes about anything it can get in quantity, depending upon availability.

The young depend principally upon crustaceans, insects, and smaller reptiles. The larger alligators, over 5 feet in length, consume a greater proportion of vertebrates. In suitable marshes, they may feed extensively upon muskrats, and, throughout their range, prey on the various birds attracted to open water.

We do not view this predation with concern. Although alligators eat many muskrats, it is questionable whether they do or can seriously deplete the muskrat population. In the early 1920's, when the marshland was first opened up for intensive exploitation of fur resources, there were tremendous numbers of alligators and, at the same time, muskrats were produced in numbers probably never again to be equalled.

Predation on birds is slight. Fortunately, alligators feed little during the winter when ducks and other migratory waterfowl are present. Except for accidental taking of the eggs and young of marsh-nesting species, birds seem to offer considerable difficulty of capture which probably depends on chance. Predation would be heaviest on the birds present in greatest numbers and frequenting the margins of water where alligators are prone to feed. This was indicated by the stomach material, the birds taken in most numbers being

the most common residents of the marsh.

Alligators are too valuable a resource to be eliminated from the marsh fauna for the sake of predator control. Since the skins furnish a source of leather, the economic returns compensate for the loss of some muskrats and boat-tail grackles. There is also justification for protecting a native species that is far reduced. On the other hand, the alligator population should not be allowed to reach proportions where capable of real damage to more desirable wildlife.

INFLUENCE OF ALLIGATORS ON THE ENVIRONMENT

Alligators may be considered beneficial, particularly to waterfowl, under certain conditions. Natural ponds, in areas of otherwise dense, impenetrable vegetation, are frequented by alligators and their use tends to keep these ponds open. Without the activity of the alligators such waters would soon be invaded and choked by plant succession. These openings are naturally attractive to waterfowl, a fact known to alligator hunters who find the ponds, and consequently the alligators, by observing the flights of herons, egrets, and other birds.

BREEDING AND NESTING DATA

Alligator hunting practiced without restriction on the public lands and waters of the coastal marshes of Louisiana, starts during the spring months and continues throughout the summer and early fall. This long season inevitably leads to the loss of breeding animals and their young during the period of reproduction. With most species of wildlife taken for sport or economic return, it has been possible to establish closed seasons at the time of breeding as a measure of conservation. This is not entirely feasible for the alligator, since the animal hibernates, and it must be hunted during the warmer months.

This conflict prompted an investigation of the reproductive habits of the alligator to seek means of regulating the take to eliminate or at least mitigate the hunting effects on the breeding population during the breeding season. Again the alligator hunt provided our largest source of information. In addition to securing many carcasses for internal examination, we obtained the assistance of hunters for supplementary field observations. When refuge personnel could not be present, the hunters examined the larger females for the presence and stages of egg development.

Data on reproduction were obtained principally through post-mortem examination of females, supplemented with a few observations on nesting, including one record of the period of incubation.

At just what time of the year alligators actually breed we were not able to determine. Mating may commence fairly early in the spring (Kellogg, 1959, p. 12), possibly soon after air and water temperatures become high enough for normal activity. We think, however, that effective breeding does not occur until late May or early June when the eggs erupt from the ovaries and descend into the oviducts.

From April 10 to May 26, 1947,[1] 10 mature females were examined. The eggs were within the ovaries in all, although late in May they were so large

[1] This section includes observations of sexual development during the spring of 1947, giving a complete account of the annual reproductive cycle.

(1 to 1-3/8 inches in diameter) that the period of ovulation must have been close.

TABLE 3.—REPRODUCTIVE DATA FROM FEMALE ALLIGATORS

Date	Length of Female	Location of Eggs
April 10, 1947	7′ 0″	in ovaries
" 10, "	7′ 0″	" "
May 3, "	7′	" "
" 15, "	7′	" "
" 16, "	6′ 8″	" "
" 16, "	6′ 0″	" "
" 16, "	6′ 1″	" "
" 21, "	6′11″	" "
" 21, "	6′ 6″	" "
" 26, "	6′ 8″	" "
June 3, 1946	6′	in oviducts
" 4, "	5′	" "
" 4, "	7′ 1″	" "
" 6, "	6′11″	" "
" 6, "	6′ 6″	" "
" 7, "	7′	" "
" 9, "	7′ 8″	" "
" 26, "	7′	" "
July 3, "	7′ 9″	eggs laid
" 4, "	6′	" "
" 4, "	7′	" "
" 5, "	6′	in oviducts

In 1946, the first adult female was examined on June 3, when the eggs were in the oviducts and encased with shell. All mature females checked during this month had well developed eggs, with shells, in the oviducts. One observation was made of a female containing eggs on July 5.

Table 3 lists all mature females examined, with dates of examination, length of specimen, and the state of sexual development indicated by the presence or absence of eggs and the location of eggs within the genital tract. In some instances the specimen was not measured prior to skinning and the length given represents the length-class in which the skin was subsequently sold.

By July 1, nest construction and laying had started. One freshly constructed nest was found on July 2, and 2 more were found the next day. On July 4, two adult females were killed by hunters using boats in ponds far back in the marsh. These alligators had laid their eggs, although the hunters had failed to locate any nests.

Since females had well developed eggs in the oviducts throughout June, this was an indication that nesting activities would start during that month and continue at least into July (one female with eggs July 5). This was confirmed by the finding of nests during the first few days of July. We were unable to determine whether any nests started late in July, as hunting ceased on July 7.

One record on the length of incubation was obtained. During a marsh-buggy trip on July 3, a nest was found in an inaccessible area. It was not observed again until the resumption of hunting in late summer. At first examination it had just been completed and the eggs freshly laid. At the final inspection September 1, the eggs were still present. When one was removed and opened, a fully developed young alligator fell out on the nest and crawled into the water. The nest was not further disturbed, since it was evident that hatching was imminent. This record indicates that incubation requires about eight weeks.

Our data suggest that the various phases of reproductive development may be divided as follows:

April–May—maturation of eggs in ovaries

mid-May–mid-June—ovulation and fertilization

mid-June–mid-July—nest building and egg laying
mid-August–mid-September—hatching of young

Some allowance has been made for variation in the foregoing sequence, but perhaps not enough to cover all early or delayed breeding. Under average conditions we would expect the norm of reproduction within the time limits indicated.

Females attain considerable size before reaching sexual maturity. Only one mature female examined by a hunter was found less than 6 feet long, and probably approached 6 feet in length but not measured prior to skinning. The length assigned in this case (5 feet) is that by which the hide was sold. Many 4 and 5-foot alligators were examined and all of the 4-foot and smaller 5-foot females were definitely juveniles. As the size approached 6 feet, some showed signs of puberty. Enlargement of the Graafian follicles was noted in a few of the larger 5-foot females, but these would not have produced eggs until the following season.

In making egg counts to determine the average number produced, we depended entirely upon enumeration of those maturing within the ovaries or contained within the oviducts. No egg counts were made in the nests examined. The number in females varied from 1 to 38, averaging 25. The smallest numbers were usually recovered from the smallest females, or those which had just attained maturity. One female, exactly 6 feet long, contained only one egg and another of about the same length held 12 to 14 eggs (hunter's estimate). Larger alligators, 7 feet or more in length, normally lay 30 or more eggs.

While the eggs are incubating, the female remains at the nest site. Whether she actually guards the nest has not been demonstrated, but the fact that she stays with the nest is indirect evidence that she assumes a protective role. Reese (1915, p. 20) doubts that the alligator defends the nest but bases his opinion on the fact that they do not attack men or bears disturbing the nest. This is probably the case as alligators have a real fear of man and will not attack without extreme provocation. No such reason, however, would prevent the animal from driving away raccoons, mink, snakes, and other predators. Such predators are so abundant on the Sabine marsh that it is difficult to see how a clutch of eggs could remain unmolested for so long as two months without some protection. On two separate occasions we have examined alligator nests while the females lay plainly visible only a few feet away in the marsh. These females did not offer to attack, neither did they make any effort to escape.

The adult female has a burrow within a few feet of the nest. This she uses during incubation, and the young use it as a retreat later. The young are known to remain in the vicinity of the nest for some time. A number of times we have observed year-old alligators at the site of an old nest. Occasionally, where a nest was near a fair sized pond, we found specimens of all age-classes up to 3 years occupying the pond together.

In the coastal parishes of Louisiana, the alligator is considered an outlaw species and may be hunted without restriction. It is killed at all times of the

year except during the winter when dormant in underground burrows. With a year-long open season, hunting obviously must take place during the breeding season. The reproductive activities extend over so long a period that some disturbance from hunting seems unavoidable. If the alligator is worth preserving as a natural resource, however, it must be given some protection to minimize the excessive losses which are rapidly and inexorably decimating the breeding reserve of the species.

Some protection is warranted during the crucial period between egg laying and hatching of the young. If the female is destroyed then, there is little likelihood that the eggs will hatch. The degree of protection needed in the nesting period may depend largely on the amount of control possible over hunting activities. Where no hunting supervision is possible, it would be advisable to establish a closed season mid-June until mid-September. If some supervision is maintained, it may be desirable to prohibit killing those near nests or limit hunting to that from boats on open waterways. Breeding females, on the Sabine Refuge, are seldom killed in the canals and bayous. Concentration of hunting in such accessible areas holds the loss of breeding population to a minimum; most of the breeding alligators are some distance back in the marsh where they must be hunted on foot.

Hunting, as conducted on the Sabine Refuge, is closely supervised, and the hunters are selected partly for their reliability. Since it is possible to get dependable hunters, it is necessary only to regulate by prohibiting the taking of any specimens within 100 feet of a nest during the breeding season. On this refuge, hunting is not intensive enough to deplete seriously the breeding population at other times of year. With this minimum of control, it should be possible to maintain an annual population increment sufficient to offset the losses incurred through hunting and natural causes.

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EFFECTS OF REMOVAL OF FINS UPON THE GROWTH AND SURVIVAL OF SPINY-RAYED FISHES[1]

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Removal of one or more fins from a fish for the purpose of identification has long been a standard practice in fishery investigations. There are two principal purposes for which it is employed. For one thing, the quantitative survival of young fish to catchable size has excited much interest, as only when this is known is it possible to estimate the benefits that will accrue from stocking a body of water with extra young. Quite commonly nowadays a part or all of the fingerling fish that are planted in the course of regular fish-cultural procedure are marked by removing one or more fins. The other important use of fin clipping is in studies designed to tell the annual survival rate, rate of exploitation, and actual abundance of natural populations of fishes of commercial or usable size.

Technically, the most important difference between the two kinds of experiment just mentioned is that in the first case fish from an outside source are used, whereas in the second, native inhabitants of the body of water are employed. In addition, experiments designed to test the effectiveness of planting hatchery-reared fish usually have to deal with rather small specimens, whereas population studies are usually concerned chiefly with stock of moderate to large size. In either situation, any extra mortality caused by the marking procedure can have a distorting effect upon the results obtained. Such extra mortality can be divided into (1) mortality from infection, loss of blood, or rough handling involved in the marking process itself; and (2) continuing mortality which results from some disability which the fish suffer as a result of the absence of the fin, even after the wound is completely healed.

In general it appears that removing a fin or fins usually has no immediately fatal effects upon either large or small fishes of the kinds that have been most used in marking experiments. (In North America salmonids and centrarchids have been used oftenest.) This has been found by keeping some of the marked stock under observation for a few days or weeks after marking and comparing their mortality with that of unmarked specimens. Usually neither group suffers any significant loss.

Unfortunately, possible mortality of the second type mentioned above usually cannot be detected simply by keeping marked and unmarked individuals in captivity, for no matter how long a period. Once the wound is healed, any effect of fin removal must be such as will place the marked fish at a disadvantage in escaping its enemies, or in obtaining its food. Such effects can only

[1] A study made by the Indiana Lake and Stream Survey, sponsored jointly by Indiana University and the Department of Conservation, Division of Fish and Game. Contribution No. 384 from the Department of Zoology, Indiana University.

be discovered in habitats where natural enemies are present and where the customary degree of competition for food exists. To the writer's knowledge the only place where an experiment of this sort has been performed is at Cultus Lake, British Columbia. Foerster (1936) marked a part of the young sockeye salmon leaving the lake in two years, with the following result:

Year-class	Mean length of migrants	Fins removed	Per cent return as adults		Ratio
			Marked	Unmarked	
1925	92 mm.	Ventrals & adipose	*0.88*	*2.49*	0.35
1926	81 mm.	Ventrals & ½ dorsal	*1.34*	*3.20*	0.42

Because other experiments showed that there are practically no non-native sockeye at this lake, the obvious interpretation to be put on these data is that the marked sockeye were at a serious disadvantage as regards survival. Their expectation of living to maturity averaged only 38 per cent of that of the unmarked individuals.

It should be noticed that *in any given situation* the disadvantage of the marked sockeye was not especially great. For the 1925 year-class, the instantaneous mortality rate corresponding to a survival of 0.88 per cent is $-\log_e (0.0088) = 9.34$; while that corresponding to a survival of 2.49 per cent is 8.30. Thus in each successive day of their life the marked sockeye were only $9.34/8.30 = 1.13$ times as vulnerable as were the unmarked ones, to the prevailing causes of death. More accurately, 13 per cent represents the *average* excess mortality suffered by the marked sockeye in all situations encountered during their two and one-half year's absence from the lake. The corresponding figure for the 1926 year-class is 11 per cent. These considerations illustrate the general principle that a small change in the day-to-day effectiveness of a cause of mortality can produce a very striking change in the number of individuals which survive it, when it operates for enough days to kill a large part of the original stock. To take an example from another field, in the case of prolific marine fishes like the cod, the ten-fold or greater difference between a "dominant" and a "weak" year-class in the commercial fishery might easily be determined by quite a small difference—of the order of 5 per cent or less—in the number of animals preying upon eggs and larvae.

Returning to the matter of marking fish, a less important but equally interesting question is whether or not marking decreases a fish's rate of growth. Apparently Dr. Forester has not commented on the relative sizes of the survivors of the marked and unmarked sockeye in the experiments just cited. The writer (1946) found that medium-sized fin-clipped lake fishes of Indiana (for example, *Lepomis macrochirus, L. microlophus, Pomoxis nigromaculatus, Huro salmoides, Perca flavescens, Ameiurus natalis*) suffered little if any retardation in growth, as shown by the fact that they remained randomly distributed throughout the size-frequency polygon of their age-group, for one growing season at least. This

procedure, however, would not detect any *small* handicap that the fish might have suffered.

METHODS

The results obtained with salmon indicate the necessity for examining differential mortality and growth among other fishes in other habitats. A preliminary experiment was done in the late summer of 1945 in a pond of the Wawasee State Fish Hatchery, Indiana, through the courtesy of Supervisor of Fisheries Harry Young. In 1946 Mr. D. R. Hughes, Director of the Division of Fish and Game, made available the ponds of the Tri-Lakes State Fish Hatchery at Columbia City, Indiana, for various experimental purposes, and determinations of the effects of marking were continued there under the care of Superintendent Forest Born. The general procedure has been to stock each pond with a mixture of fish fairly closely representing what occurs in natural lakes of the region. Included in this mixture were marked and unmarked individuals of several species, whose differential survival and growth were to be tested. The kinds of fish used to date have been fingerling largemouth bass (*Huro salmoides*), adult bluegill and redear sunfish (*Lepomis macrochirus* and *L. microlophus*), and yearling perch (*Perca flavescens*).

In marking, fins were cut off using straight-bladed bone forceps. No anesthetic was used. The control fish and those marked in various ways were taken in rotation so that the only size differences between comparable groups would be those incidental to random sampling. At the start and finish of each experiment the fish were measured to the fork of the tail, using the closed mouth as the anterior point of departure. Weights were taken individually for larger fish, while smaller ones were weighed in bulk.

EXPERIMENTS WITH YOUNG BASS AND PERCH, 1945

In mid-August largemouth bass of the 1945 hatch were stocked in a half-acre pond at Wawasee, after being marked in one of 6 different ways: removal of either the left ventral fin (LV), the right ventral (RV), both ventrals (BV), the left pectoral (LP), the left pectoral and left ventral (LPLV), or both pectorals and both ventrals (BPBV). A group of unmarked bass was used for controls; but when the pond was drained in October, it was found that additional unmarked bass of varied sizes were present so that no strict comparison between marked and unmarked individuals was possible in respect to either growth or survival. The strays presumably arrived via a drain from the hatchery where considerable quantities of bass were handled during this period.

At the same time the bass were put in, the pond was stocked with age I perch which had been seined from Winona Lake and were marked in four ways: LV, BV, LP, LPLV, plus an unmarked group (NM). In this case no "wild" perch seem to have been present, and since they were not handled in the hatchery, there would be no reason to expect them.

Other fish put in the pond in August included half a dozen spotted gar (*Lepisosteus productus*), a few bowfin (*Amia calva*), several large channel cats (*Ictalurus punctatus*) of 7–10 kilograms

weight each, some bullheads (*Ameiurus natalis*), and a few sunfish (*Lepomis*) of various species. It was hoped that the activity of these larger fish would reduce the bass and perch populations to about half their original number, but, as shown in Table 1, there was in fact relatively little mortality. In the case of the perch only 10 fish died out of a total of 125. Though all of these were marked individuals, obviously this experiment alone would scarcely even suggest that the marked perch were less viable. With bass no comparison of marked and unmarked can be made, but it would seem that survival decreases as the number of fins removed increases. The order of decreasing percentage survival is: LP, RV, LV, LPLV, BV, BPBV. The difference in survival rate between adjacent members of this series is always non-significant, but the overall effect can be tested by comparing those lacking one fin against those lacking two or more:

	Died	*Survived*	*Total*
One fin off	31	194	225
Two or more fins off	58	167	225
Total	89	361	450

This schedule can be compared with the most probable or random distribution calculated from the marginal totals:

44.5	180.5	225
44.5	180.5	225
89	361	350

$$\chi^2 = 13^2(2/44.5 + 2/180.5) = 9.47.$$

The test of significance of this deviation from expected frequencies, using Yates' correction, gives $\chi^2 = 9.5$, corresponding to 99.8 per cent confidence that it is not the result of chance. Thus it can scarcely be questioned that the removal of two or more fins did have a small unfavorable effect upon survival in the course of two months, as compared with removal of a single fin. The mean survival of the fish which lacked one fin was 86.2 per cent and of those lacking 2 or more fins (usually 2) was 74.2 per cent. Corresponding instantaneous mortality rates are 0.149 and 0.299 respectively, suggesting that the extra mutilation doubled the mortality rate. However, when the total mortality is so small, it would be rash to say that a discrepancy of this magnitude would persist for any important length of time.

TABLE 1.—SURVIVAL OF LARGEMOUTH BASS AND PERCH AT WAWASEE, AUGUST 15–OCTOBER 20, 1945, AND THEIR LENGTH ON OCTOBER 20

Largemouth bass

	LP	*LV*	*BV*	*LPLV*	*RV*	*BPBV*
Initial number	100	100	100	100	25	25
Final number	94	77	74	75	23	18
Length	66.1	66.4	66.7	66.4	62.8	60.3
St. deviation	3.46	3.52	4.63	5.61	5.00	4.01

Perch

	NM	*LP*	*LV*	*BV*	*LPLV*
Initial number	25	25	25	25	25
Final number	25	23	22	20	25
Length	106.4	106.3	105.9	106.2	105.6
St. deviation	11.00	8.00	7.96	7.05	8.08

Considering the length data in Table 1, there is perhaps a suggestion that the marked perch grew somewhat less rapidly than the unmarked ones, but the difference is far from significant. Among the bass the lots of 100 were all taken randomly from the same group, and there are no differences worth noticing among them. The RV and BPBV groups were taken randomly from another group, and the BPBV's average 2.5 millimeters shorter. The difference is suggestive but scarcely significant (confidence coefficient = 91 per cent).

EXPERIMENTS WITH YOUNG BASS, 1946–47

Tri-Lakes' ponds 1 and 2 were used, of 0.47 and 0.39 acre extent, respectively. Both were stocked in May and early June, 1946, with a large number of adult bluegills, a considerable number of black crappies (*Pomoxis nigro-maculatus*) and a few spotted gar and largemouth bass. In neither pond was there any natural reproduction of the bass because, in Pond 1, the 5 bass used were not put in until after spawning season and, in Pond 2, only 1 bass was used. The ponds were stocked with age 0 fingerling bass July 17–18, 1946, taken from another pond (No. 8). Two-thirds of the bass planted were marked by removing fins, as follows:

Pond 1: 100 left pectoral (LP), 100 both ventrals (BV), 100 not marked (NM).

Pond 2: 100 left pectoral, 100 left pectoral and both ventrals (LPBV), 100 not marked.

The range of variation in size is indicated in Figure 1.

The ponds were drained November 18–20, 1946, and as many fish as possible were removed. In Pond 2 recovery of the fish was practically perfect, as it drained well and the bottom was mostly free of vegetation. In Pond 1 recovery was less successful because of abundant algae and a covering of ice on some parts of the surface. However, it is felt that the marked fish would be as likely to be missed as the unmarked, so that the only effect of incomplete recovery would be to dilute any significant difference that may exist. The number of bass recovered, of each sort, is shown below:

	NM	*LP*	*BV*	*LPBV*
Pond 1	42	39	28	—
Pond 2	62	40	—	57

To ascertain the overall significance of these figures, a comparison can first be made between all marked and all unmarked individuals, as follows:

	Not marked	*Marked*	*Total*
Recovered	104	164	268
Not recovered	96	236	332
Total	200	400	600

A test of the significance of the association between marking and greater mortality gives $\chi^2 = 6.2$, which for 1 degree of freedom corresponds to 98.7 per cent confidence, so here again there is very good assurance that marking does impose a real handicap on the young bass. Over the period of time involved here, its most probable average effect was to decrease survival rate from 42 to 33 per cent in Pond 1, and from 62 to 48 per cent in Pond 2 (the former figures including some incomplete recovery). A better comparison would be between the corresponding instantaneous mortality rates, which were 0.87 and 1.11 for Pond 1, and 0.48 and 0.72 for Pond 2; the excess being 0.24 in each case. Assuming that Pond 2 represents the normal mortality, the marking can be

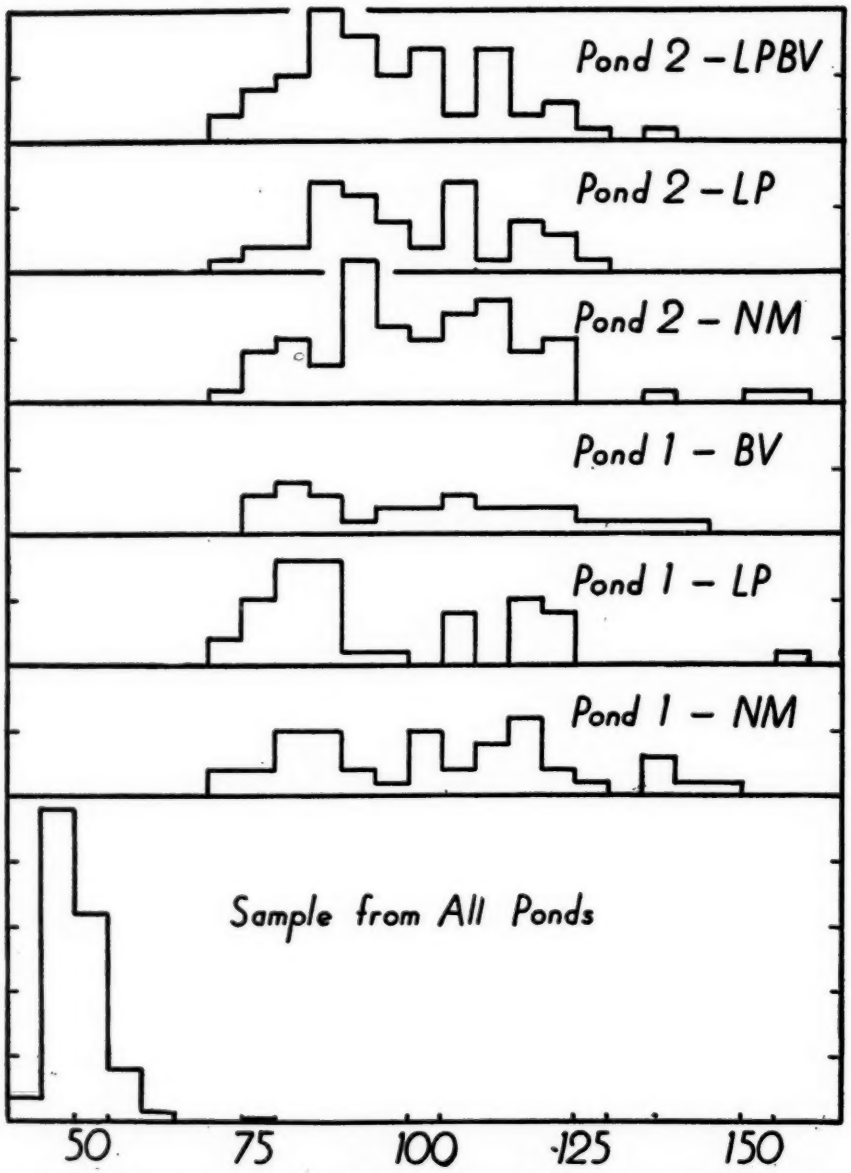

FIG. 1.—Length frequency distributions of largemouth bass used in the 1946 experiments. The lowermost distribution is that of the bass when they were first put in the ponds, July 17-18; the other distributions show the sizes achieved by the different marked and unmarked groups, November 18–20. (Abscissa—fork length in millimeters; ordinate—each division represents 20 fish in July, and 5 fish in November.)

said to have increased the instantaneous mortality rate by 50 per cent.

In comparing the effects of different types of marks, it is impossible to demonstrate from these data that the loss of two or three fins is any more harmful than the loss of only one. In Pond 1 the LP fish suffered little more mortality than the unmarked ones, while the BV group was much less numerous. In Pond 2, however, the LP fish were scarcest, while LPBV numbered only 5 fewer than the unmarked. It is most likely that these apparent discrepancies are the result of sampling error, for regardless of whether removal of a pectoral fin or the ventral fins is more disadvantageous, we should certainly have expected removal of both to be more serious than either one separately. (It is, perhaps, just conceivable that the LPBV fish, because of their greater handicap, might have tended to frequent parts of the habitat less exposed to predation than those preferred by the unmutilated or less mutilated individuals.)

During the winter of 1946–47 the ponds were ice-covered for a protracted period and considerable mortality occurred. All the fish of Pond 1 succumbed. Pond 2, however, had a considerable number of surviving bass and bluegills. These were enumerated in May and then left in the pond for the summer, to be checked again in October. The complete history of survival in Pond 2 to date is as follows:

	July 18, 1946	*Nov. 19, 1946*	*May 16, 1947*	*Oct. 27, 1947*
NM	100	62	27	23
LP	100	40	12	11
LPBV	100	57	16	17
Total	300	159	55	51

The over-winter mortality was 67 per cent for the whole group, and again the marked fish suffered most: survival was 30 per cent for LP's and 28 per cent for LPBV's, as compared with 44 per cent for the unmarked ones. A test of significance gives $\chi^2=3.5$, indicating that the difference between marked and unmarked falls short of the 95 per cent level of confidence. However, there is no reason to question its reality when it follows the same pattern as during the previous summer; the sum of the two chi-squares is 9.7, corresponding to 99.8 per cent confidence in the reality of the total effect. It is difficult to say what role the direct effect of severe winter conditions may have played. Offhand it would perhaps seem unlikely that asphyxiation would operate selectively as between marked and unmarked, yet in biological experiments the unlikely eventuality so often proves to be the correct one.

During the winter and early spring the survival of unmarked fish was 43.5 per cent and of marked fish was 28.9 per cent, corresponding to instantaneous mortality rates of 0.83 and 1.24. The increase due to the marking is therefore 0.41, which again is 50 per cent of the "normal" instantaneous mortality rate of unmarked fish.

During the growing season of 1947 there was very little mortality—only 4 specimens. The bass at this time had no larger predacious fish as enemies, and they were of a uniform enough size to make cannibalism improbable. (The apparent *increase* in LPBV's may have resulted form a fish being overlooked in the spring draining, or from inaccurate recording.)

The question of a possible effect of

marking upon the growth of the bass is examined in Table 2 and Figure 1. During 1946 the bass in the two ponds grew at about the same rate. The average length achieved by all the unmarked ones exceeded that of the marked ones by 4.7 millimeters. This difference is 2.12 times its standard error, and must be considered significant. A part but not all of the difference results from a larger proportion of unusually large fish among the unmarked ones. There is a well-known tendency for a few of the bass in any brood to greatly exceed the remainder in growth. In these data there are 8 unmarked bass, out of 104, which fall in the 130 millimeter or larger groups, whereas only 5 marked ones out of 164 do the same.

We naturally ask ourselves whether differential growth and differential survival may not be associated. (1) If *larger* bass are more exposed to predation, and marked ones are more vulnerable than unmarked, then the greater toll taken of marked ones would automatically result in the average size of the survivors being less than that of the survivors of the unmarked ones at the end of the season, even though individual marked and unmarked fish, of comparable sizes, grew equally well. (2) If marking primarily decreases rate of growth and if *smaller* bass more readily succumb to predation, etc., then the observed excess mortality among marked bass could be an indirect effect of the reduced rate of growth. As will be described immediately, during the ensuing winter mortality did definitely bear more heavily on larger fish, both marked and

TABLE 2.—LENGTHS OF LARGEMOUTH BASS STOCKED IN PONDS 1 AND 2, IN MILLIMETERS

	Pond 1			Pond 2			Both Ponds	
	NM	*LP*	*BV*	*NM*	*LP*	*LPBV*	*NM*	All Marks
July 17–18, 1946								
Number	96*	—	—	91*	—	—	187*	—
Mean length	47.6	—	—	47.9	—	—	47.8	—
St. deviation	4.2	—	—	4.5	—	—	4.3	—
Nov. 18–20, 1946								
Number	42	39	28	62	40	57	104	164
Mean length	102.0	93.6	100.5	100.0	97.1	95.0	101.0	96.3
St. deviation	19.9	19.7	19.4	17.2	14.2	15.6	18.4	16.7
May 16, 1947								
Number	—	—	—	27	12	16	—	28
Mean length	—	—	—	98.7	90.8	93.4	—	92.3
St. deviation	—	—	—	17.4	8.2	14.9	—	12.4
Oct. 27, 1947								
Number	—	—	—	23	11	17	—	28
Mean length	—	—	—	179.4	175.4	179.1	—	177.0
St. deviation	—	—	—	28.2	11.7	28.1	—	22.8

* A sample of all of the fish stocked, marked and unmarked.

unmarked. Hence the first hypothesis above is to be favored, on the basis of present information, as a partial or complete explanation of the observations, though it is far from proven.

Between November 1946 and May 1947 the bass in Pond 2 exhibited a decrease in average size: The unmarked ones from 100.0 to 98.7 millimeters, and the marked ones from 96.3 to 92.3 millimeters. Though small, these decreases are evidently real, and must be ascribed to selective mortality of the larger fish. This is evident because, on the one hand, the largest individuals almost completely disappeared: only 1 specimen was 130 millimeters or larger, as compared with 13 in the fall. Furthermore, the fish individually had evidently made some growth because the minimum size moved up from the 70 to the 75 millimeter group.

During the summer of 1947 both the marked and the unmarked bass in Pond 2 grew rapidly, the average increase being 80 millimeters for each group, so that no differential growth is indicated during this period. But we cannot be sure it was wholly absent because the 4 unmarked ones which disappeared might, by analogy with the previous winter's experience, have been larger-than-average specimens.

SURVIVAL AND GROWTH OF ADULT BLUEGILLS

On May 22, 1947, Ponds 1 and 4 at Tri-Lakes were stocked with marked and unmarked bluegills taken from among a group of age II individuals that had been reared in Pond 7. In Pond 1 there were 200 fish used, divided equally into unmarked, LP, BV, and LPBV groups. In Pond 4, 160 fish were marked in a similar manner. During the summer fishing season (June 16 to August 31) some fish were caught from each pond. On October 27 Pond 2 was drained and on October 29 Pond 4. Both drained easily and an almost complete recovery of the fish was made. The result is given in Table 3. It is evident that no significant differences exist between the various marks and the unmarked group in respect to either numbers caught or numbers surviving. In both ponds fishing was the principal cause of mortality, but a total of 50 fish in Pond 1 and 25 in Pond 4 are not accounted for, and among these the marked fish are slightly more numerous, relatively.

The mean lengths of these groups of fish are also examined in Table 3. The standard deviation was 8 or 9 millimeters in nearly every case, so obviously

TABLE 3.—SURVIVAL AND GROWTH OF ADULT BLUEGILLS

	Pond 1				Pond 4			
	NM	*LP*	*BV*	*LPBV*	*NM*	*LP*	*BV*	*LPBV*
Number stocked, May 22	50	50	50	50	40	40	40	40
Number caught, June 16–Aug. 31	24	24	22	20	10	13	6	12
Number remaining, Oct. 27–29	15	14	17	14	26	23	23	22
Not accounted for	11	12	11	16	4	4	11	6
Average length when stocked	140.0	138.6	138.4	138.6	135.9	136.4	138.1	135.1
Average length of catch	149.6	146.9	146.8	149.8	139.0	143.1	144.2	141.7
Average length of survivors	165.0	166.0	166.0	163.6	145.0	142.9	149.1	142.5

none of the small apparent differences are significant. In Pond 1 the average unmarked fish grew slightly less than the average marked one, while in Pond 4 it grew slightly more. The lengths of those caught out by fishermen similarly show close agreement between marked and unmarked, so there is not even a suggestion of any effect of marking upon rate of growth.

of marked with unmarked fish can be made because the latter were stocked over a wider range of dates and their mean length was considerably less than that of the marked ones—a fact which would favor a greater survival rate among them, as well as a more rapid growth. As shown in Table 4, the survival rate of unmarked individuals was 65 per cent, as compared with 72 per

TABLE 4.—SURVIVAL AND GROWTH OF LARGE REDEAR SUNFISH

	Number		Mean length		Standard deviation	
Fins removed	June 11	Oct. 29	June 11	Oct. 29	June 11	Oct. 29
Left ventral	18	13	186.4	199.6	26.3	18.9
Both pectorals and both ventrals	18	9	185.0	190.6	27.2	9.2
Not marked	105	68	174.8	197.0	34.8	21.0

SURVIVAL AND GROWTH OF LARGE REDEARS

Of 141 adult redear sunfish stocked in Pond 5 at Tri-Lakes in the spring of 1947, a small group was marked. This consisted of 36 individuals stocked on June 11, after removal of the left ventral fin from a half of them (LV), and all four paired fins from the other half (BPBV). Survivorship and growth of these fish is shown in Table 4. The excess of survival of LV over BPBV is 4 fish, and there is also a suggestion of slower growth among the more severely mutilated group. However, neither effect approaches significance, and the difference is partly explained by the capture of two large BPBV's by fishermen (235 and 244 millimeters) as compared with only one relatively small LV (175 millimeters).

Unfortunately no precise comparison

cent for LV's and 50 per cent for BPBV's, or 61 per cent for all the marked ones. Obviously there is no important indication that marked ones suffer greater mortality than unmarked ones.

DISCUSSION

As regards the adult bluegills and redear sunfish, it is gratifying to have earlier indications supported by the experiments just concluded. Evidently one need have no misgivings about removing fins from specimens 5 inches or more in length: any handicap they may suffer, either in growth or viability, is so small that it cannot be detected in samples of moderate size, and hence its possible existence may be ignored. It is important however to note that these experiments give no information on the effects of catching fish in nets for the purpose of marking them. Such

effects would have to be checked by a different type of experiment.

The results of marking the small bass are quite different. They indicate that loss of fins has an important unfavorable effect upon survival, and possibly, a rather small effect upon rate of growth. The magnitude of the differential mortality corresponds to an extra 0.65 added to the (instantaneous) mortality rate in the course of less than a year's time. The marked fish were at no further disadvantage during the following summer, so that it is quite possible that 0.65 represents the whole of the handicap they would suffer. Such a differential would mean that, whatever the total mortality and net survival rate in an experiment using the marked fish, the number recovered would be only 52 per cent of the number characteristic of unmarked fish.

A differential of this magnitude is obviously of importance, though equally obviously it would not make the results of a marking experiment completely useless. It is somewhat less than Foerster found for sockeye (38 per cent) in spite of the fact that the sockeyes were considerably larger when marked. It is interseting that the greater part of the excess mortality among the bass took place not in summer when they were small, but during the winter season, after they reached 95 millimeters in length. There is some possibility perhaps that the severe winter conditions may have decreased survival rate selectively. Hence, before taking the above 52 per cent as an even approximately representative figure, it would be desirable to repeat the experiment in a pond not even partially subject to winterkill.

SUMMARY

Among young largemouth bass 48 millimeters long, living with a "normal" population of other fish, including large predators, the removal of one pectoral fin, or both ventral fins, or a pectoral and both ventral fins in July resulted in significantly decreased survival from that time to November, during which time they grew 50 millimeters on the average. The magnitude of the effect is estimated as an increase of 0.24 in the instantaneous mortality rate, or 50 per cent of the mortality rate of unmarked fish. From November to the following May the marked individuals suffered an additional 50 per cent excess mortality, which increased the instantaneous rate of 0.83 for unmarked fish to 1.24 for marked ones. The total differential of 0.65 corresponds to a survival rate, among marked bass, 52 per cent as great as that of unmarked bass. During their second summer of life, larger piscivorous fish were absent from the pond and there was no excess mortality among the marked bass as they grew from 95 millimeters to 178 millimeters.

During the winter period mentioned above, mortality was heaviest among the *larger* bass of both the marked and the unmarked groups. A similar greater vulnerability of large individuals might explain the fact that, at the end of the previous summer, the survivors of the marked individuals were significantly smaller (4.7 millimeters) than were the unmarked ones. However, it is also possible that marking affected the rate of growth directly.

Two-year-old bluegills, marked when 138 millimeters average length, suffered

very little if any extra mortality during one growing season, and were as vulnerable to capture by fishermen as were unmarked ones. The growth of the marked and unmarked bluegills was the same. Similar results were obtained from a less well controlled experiment using redear sunfish 175–185 millimeters long.

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DAILY MIGRATIONS OF PERCH IN LAKE MENDOTA, WISCONSIN[1]

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This paper is a report on daily migrations of perch (*Perca flavescens* Mitchill) in Lake Mendota during the summer months and purports to illustrate the manner in which direct underwater observation contributed to these investigations.

Anglers of Madison have known for some time that large numbers of perch could be caught at a few strategic places on Lake Mendota around sunset. Such concentrations of perch indicated a regular migration since the angling was unproductive in these same places at other periods of the day.

The questions which arose were: 1) Do aggregations of perch migrate over these areas at sundown? 2) Are the perch present at other periods but do not take the angler's lure? 3) If the perch migrate, from where do they come, where do they go, and what is their behavior at the angling station?

[1] Supported in part by the Research Committee of the Graduate School from funds supplied by the Wisconsin Alumni Research Foundation. During the last year of the project (1947) it was also supported in part by the Wisconsin Conservation Department.

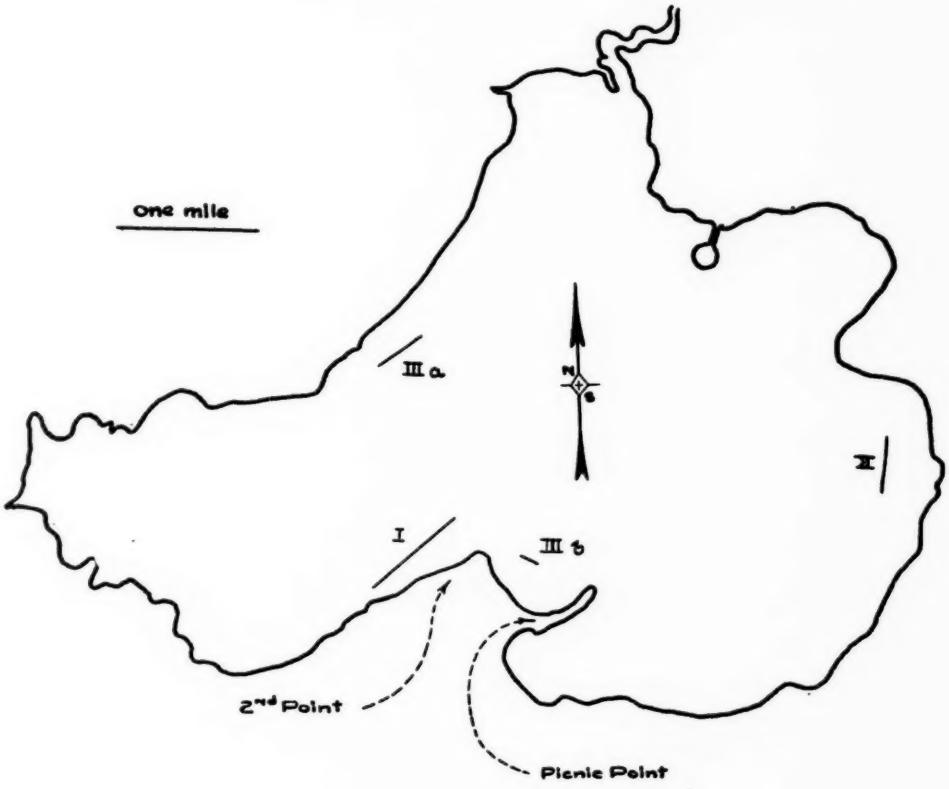
[2] Operations of this nature required the aid and cooperation of others than the authors. We are particularly grateful to Prof. R. M. S. Heffner, David LeCren, John C. Neess, Elizabeth Jones, and Stanley Ballictte for unselfish contribution of their time often at very inconvenient hours. Dr. Lester V. Whitney deserves special credit for his development of ingenious apparatus and for the planning which made possible the data from which Fig. 6 was constructed.

MATERIAL AND PROCEDURE

SITES OF OPERATIONS

Site I (Second Point Bar) represents a belt of lake bottom at the 18-foot (6 m.) bathymetric contour, ca. 875 yards (800 m.) long, 165 yards (150 m.) wide, and extending parallel to shore

from East to West. The underwater terrain there forms a shallow valley, gradually declining to the North, into the deeper water beyond. Site II, (Tenney Park) lies 1.6 miles (2.5 km.) shore from Site II and increased in density at 10 feet (3 m.) and shallower toward the South. Sites IIIa and IIIb, the control areas, represented neutral points in the lake at which observations



LAKE MENDOTA

FIG. 1. Map of Lake Mendota. Numbers I, II, IIIa and IIIb indicate the sites of observation.

East of Site I, depth 18–19 feet (6 m.). The character of the bottom at Sites I and II was very similar. Soft grey mud, 2 to 8 inches (5 to 20 cm.) deep prevailed but interspersed were small stones and a few larger rocks. Observations of a diver further established that weedbeds occurred farther towards the were made but where no migration was found to take place. The bottom at IIIa was rocky and sandy, while muddy at IIIb. Both stations were 18 feet (6 m.) deep (Figures 1 and 2).

DESCRIPTION OF GILL NETS

Between 1943 and 1946 linen nets, 5

feet (1.5 m.) in depth and 125 feet (38 m.) long were set on the bottom of the lake like a fence. Suspension sets above this depth proved inefficient, owing to the demersal habits of the perch. Each net was composed of five 25 ft. (7.5 m.) sections with meshes arranged as follows: (1) ¾ inch sq. (1.95 cm.) (50/3 linen); (2) 1 inch sq. (2.54 cm.) (45/3); (3) 1¼ inches sq. (3.18 cm.) (40/3); (4) 1¼ inches sq. (3.81 cm.) (40/3); (5) 2 inches sq. (5.08 cm.) (30/3). In 1947 only 25 feet (7.5 m.) sections of 1 inch sq. and 1½ inches sq. respectively, were employed because the bulk of the fish had been caught in these mesh sizes during previous years. Uniformity in position of net sets was ensured by taking bearings with prominent landmarks and later by setting buoys. Gill netting operations were begun in May and suspended in October or November. Early and late in the season one or two sets were made every month while nets were set during July and August once or twice weekly on the average.

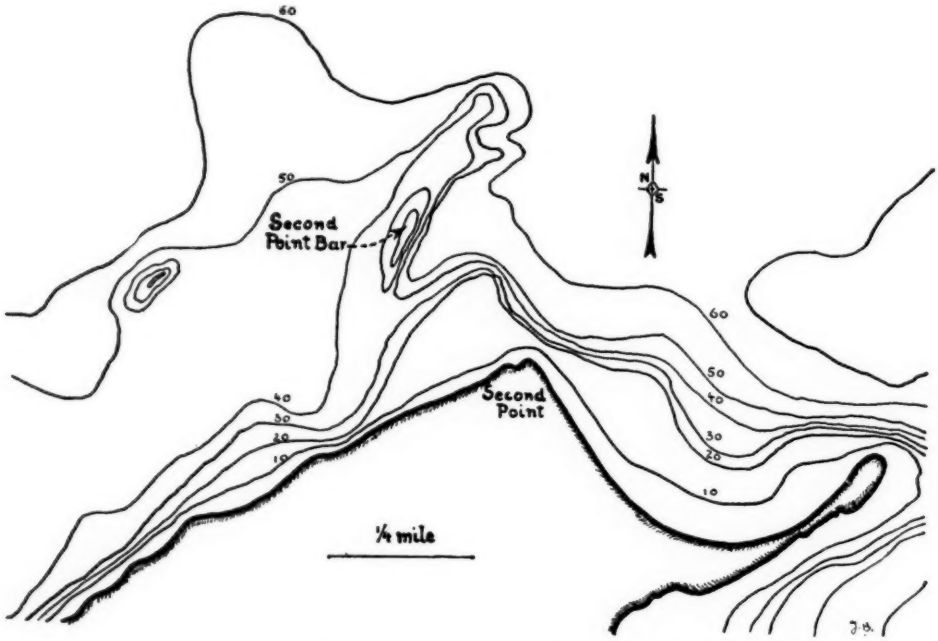


FIG. 2. Hydrographic map of Site I, Second Point Bar. Bathymetric lines at 10 foot (3.3 m.) intervals.

ELECTRIC EYE

This apparatus is an adaptation of a photoelectric recorder ordinarily employed for light measurements (Hasler and Whitney, 1946). A source of light is mounted on a metal rod opposite to and focused on a photoemissive cell at a distance of about 6 feet (2 m.). This equipment was lowered within 1 foot (30 cm.) of the bottom. When the shadow of a passing fish fell upon the

photocell the changes of potential were registered as deflections on a microammeter in the boat. To avoid attracting fish already in the vicinity, the light was switched off at 30 second intervals and the interruptions in the light beam during the other 30 seconds were recorded throughout the test period.

DIVING EQUIPMENT

Two different types of diving helmets were used singly or simultaneously a) A helmet of the diving bell type, made at the University workshops.[3] With this helmet the diver's air supply was secured by hand pumps. A surge chamber between pump and helmet equalized the pressure. b) A "Browne Lung,"[4] provided with oxygen cylinders and independent of air supply. (A similar apparatus is described by Sigler & Moen, 1947). Diving operations can be conducted in Lake Mendota with this equipment from July to the middle of September. Extension beyond either date would require a type of gear in which the diver could keep warm.

RESULTS

GILL NETTING OPERATIONS, 1943

Nets set at various hours during the day, at Site I, established that a few perch could be taken at all hours. The numbers of fish netted between 0900 and 1600 hrs. were small and could be attributed to stray schools, while nets set around sunset caught large numbers of perch.

Nets were also lowered in the vicinity of a fleet of anglers congregated at Site I waiting for "the perch to arrive." When anglers could take perch by hook and line, the nets also showed good catches, while poor angling success invariably coincided with empty gill nets. The time of arrival of the fish was checked by lowering two, or rarely three nets consecutively in the same position at hourly intervals, namely 90 min. before, 30 min. before, and 30 min. after sunset. The results tabulated in Figure 3 and the observations mentioned above corroborated the belief that perch moved onto the Second Point Bar near sundown, and also ruled out the possibility that the fish might be present but did not take the bait offered by the anglers. It appeared that the bulk of the fish arrived at Second Point Bar around sunset in the summer of 1943.

GILL NETTING OPERATIONS, 1944–46

During the war years operations were conducted as in 1943; the lack of personnel, however, curtailed severely the frequency of netting operations. The onset of the migration in early summer fell near the end of May or the beginning of June, depending on the season, and terminated around the middle of October. It began and ended gradually; the numbers of fish participating increased toward midsummer and decreased toward autumn. During the summer of 1944 a few netting expeditions were also made at sunrise to ascertain if there was a migration at that time (Figure 4). This practice was continued in subsequent years. While there seemed to be another peak in concentration of fish near the Second Point Bar at sunrise, this was not so pronounced as in the evening hour.

[3] Lent by Stanley Balliette, who also generously assisted in the diving.

[4] Diving Equipment and Supply Co., 1119 N. Water St., Milwaukee, Wisconsin.

GILL NETTING OPERATIONS, 1947

In the middle of May the onset of the migration was observed and earlier results were corroborated, namely, that perch could be taken at the customary hours near Site I as early as the end of May.

Gill nets were spaced at four stations along the shore near Second Point, 650 feet (200 m.) apart, from east to west lifted at hourly intervals, including the sunset period. No further evidence on the direction of the migration was gained in this manner but the tendency for a movement along the shore was demonstrated (see Electric Eye, 1946).

The distribution of fish over 24 hours was investigated again by net sets at three-hourly intervals. The results tallied essentially with those of previous years (Gill Netting Operations 1943a). There was evidence, however, of increased activity during the hours of darkness when compared to full daylight. The time of arrival of the perch was also tested again (Figure 5) in the manner already described (Gill Netting Operations 1943c). Detailed records of

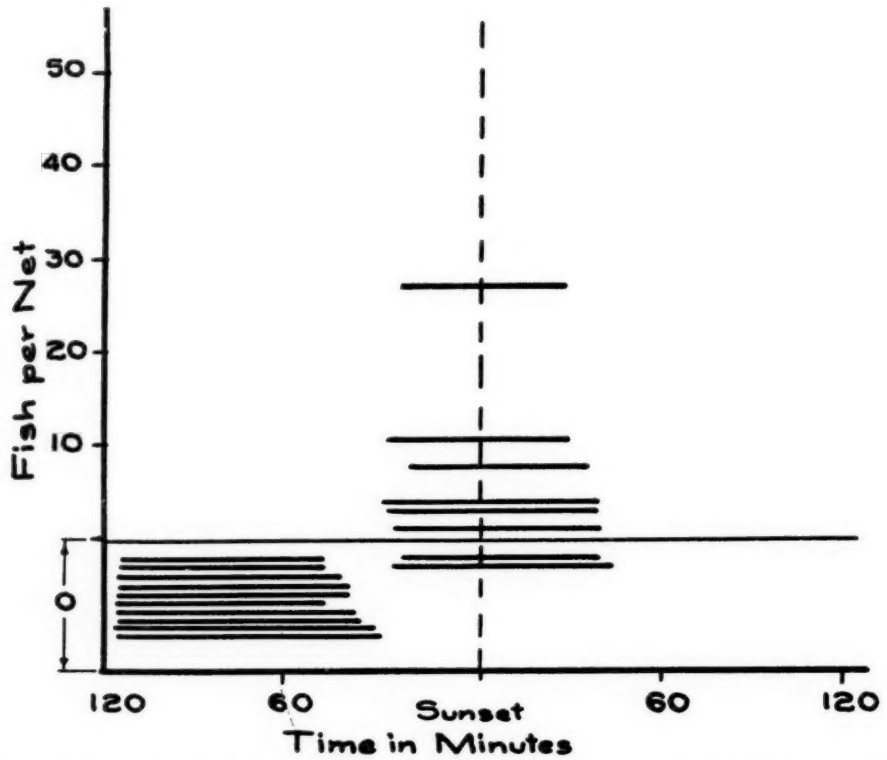


FIG. 3. Time of arrival of perch at Site I during sunset hours summer 1943. The horizontal lines represent single gill nets. The time fished is indicated on the abscissa while the numbers of fish caught in each net during that time can be read from the ordinate.

all gill net sets and catches were compiled and are kept at the Dept. of Zoology of the University of Wisconsin.

ELECTRIC EYE, 1945

The apparatus, as described, was used during this summer. Results corroborated the observations from netting that a migration or movement occurred between 1700 and 1900 hrs., the onset of this migration changing with the seasonal shift in sunset.

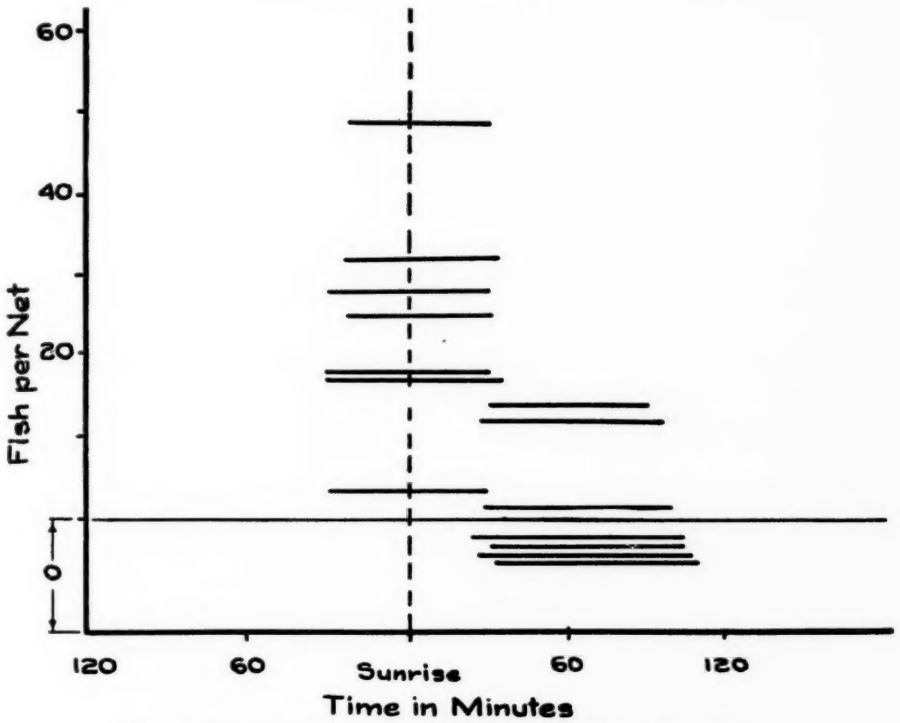


FIG. 4. Time of arrival of perch at Site I, during sunrise hours, summers 1944–47. Explanation as in Figure 3.

ELECTRIC EYE, 1946

Since one fish detector could not furnish information about the direction of movement, 4 such devices were used simultaneously in August 1946, supplemented by gill nets in their vicinity. The detectors were arranged at the corners of a parallelogram with sides of approximately 330 feet (100 m.). Six evening expeditions, where readings were taken over two and three hour periods, yielded no satisfactory conclusion as to the exact direction of the movement. It became apparent though, that the fish swam mainly parallel to shore, from East to West or from West to East (Figure 6). All sets, however, on other days did not yield results as convincing as these, causing us to distrust this finding.

DIVING OPERATIONS AUGUST AND SEPTEMBER 1947

Two excursions were made to Site I at sunrise and ten outings, covering the afternoon and evening (sunset) were distributed among various points in the lake as follows:

6 at Site I
2 at Site II
2 at Sites IIIa and IIIb

A flat-bottom workboat was used as the base of operations. The divers oriented themselves by taking bearings on the sun, visible through the water, or with the help of two anchors lowered in the North-South line. The divers were able to lower themselves to the bottom three or four times during a trip, spending from twenty minutes to one hour at the bottom in each descent.

Sunset migrations were observed at Sites I and II, but at Sites IIIa and IIIb no perch were seen at any time during the afternoon and evening. One hour to 40 minutes before sunset perch

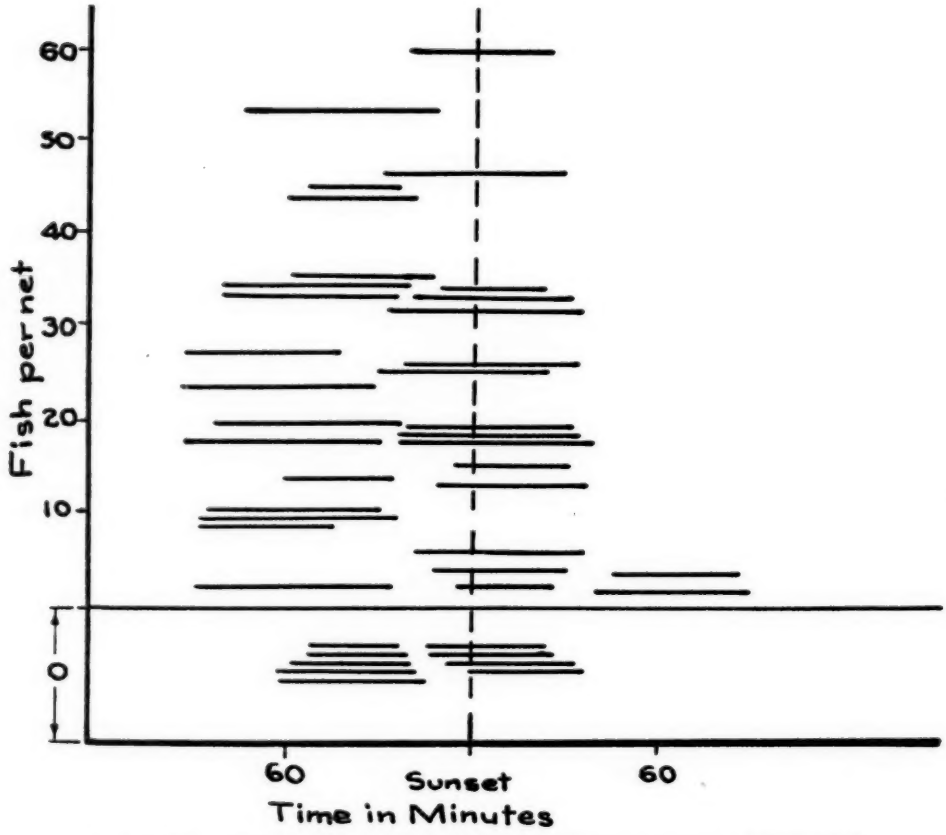


FIG. 5. Time of arrival of perch at Site I during sunset hours, summer 1947. Explanation as in Figure 3.

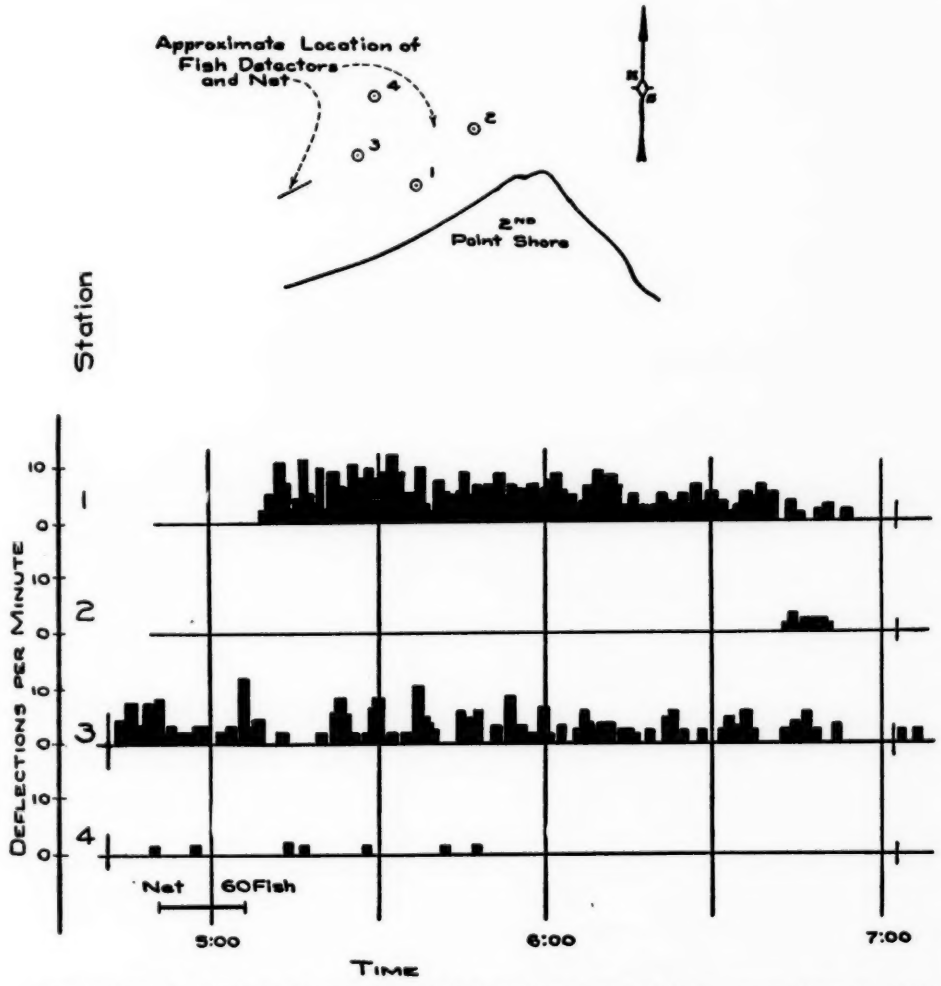


FIG. 6. Sample sheet of observations with the photoelectric fish-detectors. August, 1946. Four stations, arranged as sketched in figure, are represented. The time of observations is indicated on the abscissae. The number of deviations per minute, read from the microammeter, is represented by the columns traced in black and is roughly proportionate to the numbers of fish interrupting the beam of light.

appeared in spindle shaped schools of approximately 50 to 200 fish. The size of the individual fish was uniform within the school but showed noticeable variation from one school to the other. The fish were fairly evenly spaced within the school and swam ca. 6 inches (15 cm). apart. The schools followed each other in 1 to 3 minute intervals. Occasionally two or three schools would appear simultaneously. The direction of movement in both Sites at this time was shoreward, i.e., from North to South at Site I, and from West to East at

Site II. As the fish came beyond the bar to a depth of ca. 18 feet (6 m.) they changed their path and swam parallel to shore in either direction. This peculiar behavior offered a picture somewhat comparable to heavy traffic on a four lane highway.

These findings were tested by spacing two divers in the supposed paths of the fish, and in case of Site II by gill netting on a sandbar 32 feet (13 m.) deep, northwest of the site of observations. It had been determined previously that fish could be taken there throughout the day and it did therefore seem reasonable to suppose that the migration at Site II originated from this sandbar.

No conclusive information was obtained from the two sunrise expeditions to the Second Point Bar; it appeared as if there were another concentration of perch at these early hours of the day, though fewer fish seemed to participate in the movement, when compared to the evening hours. These observations tally with the records obtained through gill netting at sunrise from 1944 to 1947.

DISCUSSION

The direct visual observations in 1947 confirmed the findings of previous seasons, gained from indirect evidence (gill net sets & electric eye) that a daily sundown migration of perch took place during the summer months in Lake Mendota. In addition, the divers observed that the perch were not present there, previous to these periods, and therefore solved the problem posed by one hypothesis, namely that the fish were there but did not feed. The fish moved towards the shore in the hours before sunset, and, to a lesser degree before sunrise. At the 18 foot (6 m.) contour they swerved in their path and cruised along the shore. It was possible to extend observations for about half an hour after sunset on particularly bright days and it appeared that the fish dispersed rather suddenly after the sun had set. The phenomenon of migration was observed in two widely separated locations in the lake. Perch anglers restricted themselves to relatively few places on the lake in the evening, including the two sites where diving and gill netting operations were conducted. From this observation and from the examinations of the "neutral" Sites IIIa and IIIb, where no movement of perch was noticed, it might be concluded that the migration takes place in few places of the lake only. These sites show comparable depth and bottom character. It is also indicated that the same factors inducing the movement are involved. During the migration the fish stayed near the bottom consistently. Once or twice a few fish of a different species were seen in one or the other of the schools; these "intruders" were White Bass (*Lepibema chyrsops* Raf.). Smallmouth Bass (*Micropterus dolomieu dolomieu* Lac.) were observed occasionally by the divers but they never seemed to take notice of the schools of perch, even if these passed by at distances of 20 to 30 feet (ca. 8 m.). The peculiar character of the migration as witnessed by the divers accounted for the obstacles in obtaining exact results by indirect methods. It is difficult to duplicate from day to day the direction in which gill nets are set; it might depend on the direction of these nets with reference to the shoreline which group of the moving fish was taken first. The fish swimming shorewards might be

likely to entangle themselves in the nets set parallel to shore and thus be caught before those perch which cruised along the shore. This latter group, then, would have a greater chance to encounter the nets set at right angles to the shore as obstructions in their path and appear in the catches later. The taneity between sunset and the movement of fish led to a hypothesis postulating a correlation between a range of critical light intensity and the migration. Previous work on diurnal rhythms with reference to fish (Hoffman 1926, Spencer 1929, 1939, Spoor and Schloemer 1938, Welsh 1938, Nuemann 1947)

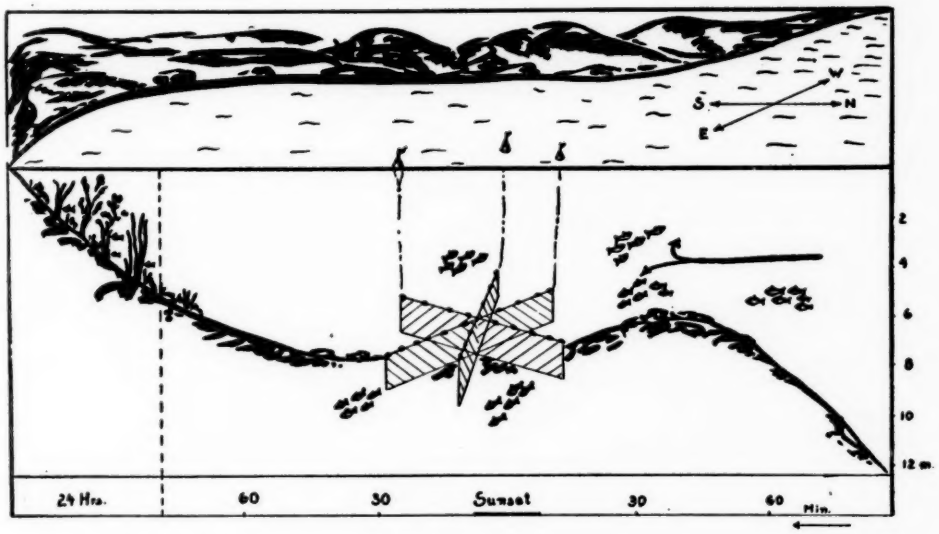


FIG. 7. Perch movements at Site I, during sunset hours. Sketched from diving observations, summer 1947.

time sequence of direction is only relative, however, and applies to a single school of fish. At any given time within the hour before sunset some schools of perch may already cruise along the shore while others may still be on their way toward the shore from deeper regions of the lake. The information obtained through gill netting and with the fish detector therefore only measured the amount of movement whereas the divers were able to record both the relative numbers and the path of the moving fish (Figure 7). The apparent simul- had shown that fish were highly dependent on changes in light intensity for the regulation of their activity levels. Very little work had been done with perch in particular, beyond the demonstration of sporadic activity (Spencer 1939). The sensitivity of fish to various light intensities can best be determined by controlled experiments and the application of such data to behavior in natural habitats may be questioned. While it seemed attractive to explain the phenomenon with changing light intensities the fact remained that more fish ar-

rived at Site I in 1947 during the hour before sunset than in the four previous years. This became increasingly difficult to reconcile with such a hypothesis. Very recent, detailed, 24 hour observations suggest day to day variations in arrival time, thus indicating that light changes alone do not fully explain this phenomenon. A forthcoming paper will amplify. The summer of 1947 showed unusually clear water (Secchi disk reading 1943–46 between 1.5 m. and 3 m.; 1947 maximum = 7.3m.). Later arrival would have been expected if a critical light intensity served directly as stimulus or releaser every day. Surface observations of large swarms of *Daphnia* at Site I, caught in small whirlpools, probably set up by temperature differences at the end of the day, led to investigations of stomachs taken from fish caught during their migration. Stomachs were also taken from fish at other hours of the day for comparison. This was done during August when crustaceans make up a considerable part of the perch's diet (Pearse and Achtenberg 1918, Langford and Martin 1940). At sunset the fish were found to be gorged with freshly ingested *Daphnia* while their stomachs at noon and sunrise, respectively, contained significantly smaller numbers of these same planksters in a partially digested state. It is planned to follow this lead during coming seasons and to conduct more intensive investigations of comparative plankton densities in various places of the lake throughout the day.

The migration is a seasonal phenomenon beginning about the end of May. It ceases, after a decline of the numbers of fish participating in it, around the middle of October. Large scale emergence of *Chaoborus* is characteristic of this season.

Various factors, in addition to light and food should be investigated since they may well serve as primary or additional stimuli. As one of those the observations of a current, by the divers and boatcrews, as Site I should be cited.

The fish seem to feed during their movement along the shore. To repeat, light may conceivably affect the movement indirectly, through its influence on the behavior of the food organisms. That it plays an important role in the phenomenon can hardly be doubted but at present it is assumed to act in conjunction with or in addition to the feeding stimulus.

SUMMARY

Apparent congregations of yellow perch, (*Perca flavescens* Mitch.) in specific locations of Lake Mendota at sunset hours during the summer months were observed and utilized by anglers for fishing purposes. These observations led to the postulation of the existence of a migration. Between 1943 and 47 the occurrence of such a migration was established and its onset and direction investigated. Gill nets, photoelectric fish detectors, and diving apparatus were employed. The migration was found to be a seasonal phenomenon occurring between May and October and to take place daily at the time of sunset; less intensively at sunrise. Diving observations showed that the fish moved shoreward in the hour before sunset and then cruised along the shore at the 18 foot (6 m.) contour until the sun had disappeared. The perch were feeding while on the bar near the shore.

Light intensity, either acting directly or through its effects on food organisms, and the feeding stimuli as such only partly explain the movement.

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NESTING CANADA GEESE ON THE UPPER SNAKE RIVER

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In the spring of 1947 the authors made a nesting survey of Canada geese (*Branta canadensis*) along a 40-mile stretch of the Snake River. The study was conducted in Jackson Hole, Wyoming, directly south of Yellowstone Park. Much of the soil of this intermontane valley is composed of glaciated gravel outwash, through which the Snake River channels have cut forming gravel bars and islands. These bars, strewn with piles of drift and scantily covered with willow and cottonwood saplings, offer unusually desirable nest sites for Canada geese. The area is about 6,500 feet above sea level in the *Picea-Abies* formation. The immediate riverbank vegetation includes a variety of flood plain types with willow-sedge, cottonwood, and climax stands of spruce and fir predominating; the upper slopes contain lodgepole pine, aspen, and sagebrush types.

The Snake River, which has its headwaters in Lewis and Heart Lakes in Yellowstone Park, enters the north end of Jackson Lake emerging at Moran through the gates of the Jackson Lake

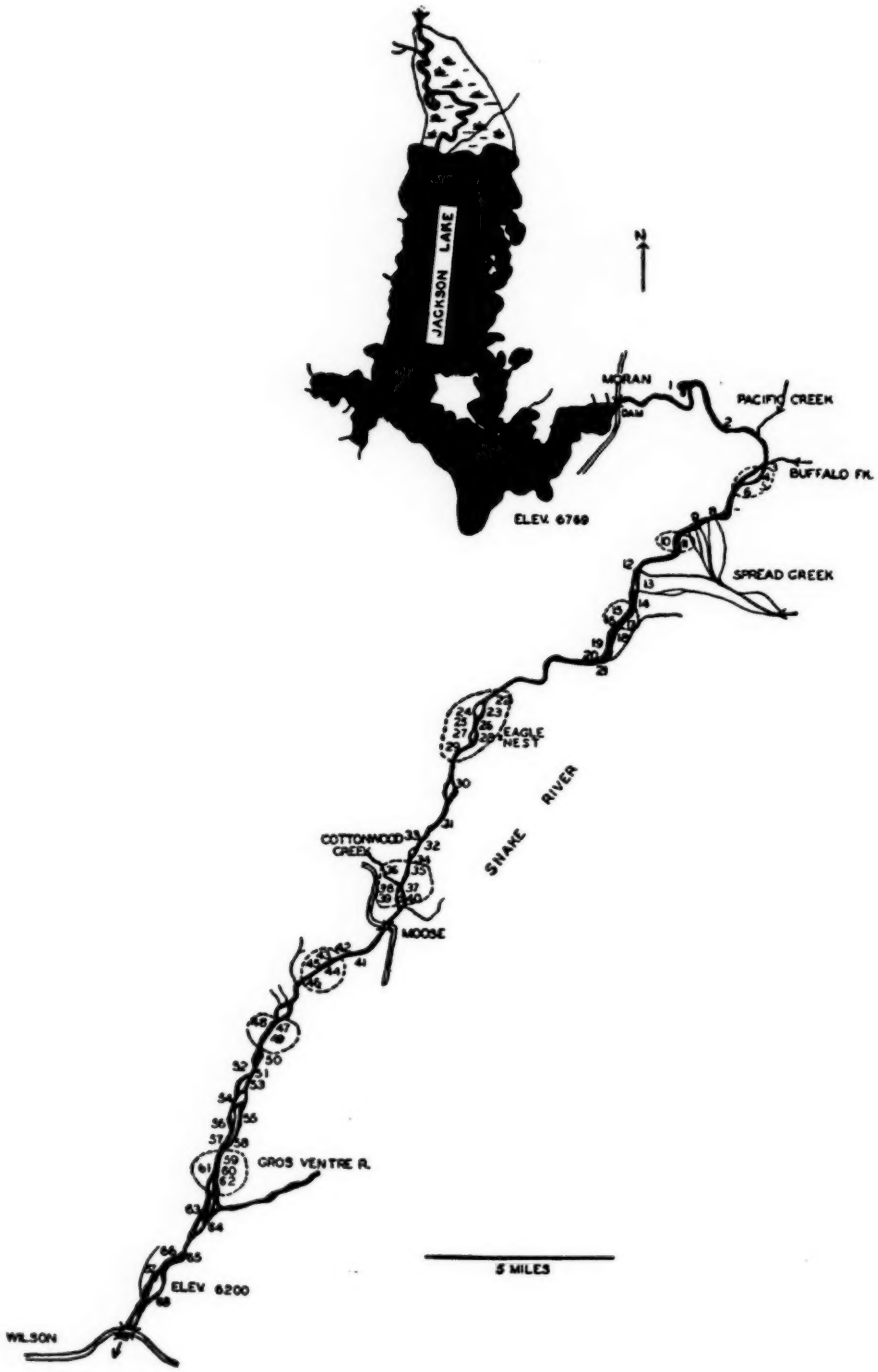

FIG. 1.—Map of Study area on Upper Snake River, Wyoming. Numbers from 1 to 68 indicate approximate locations of nests and nest sites. General nest sites are not included. Dotted lines surrounding numbers indicate groupings of nests.

Dam. The dam and reservoir are the property of the United States and are administered by the Bureau of Reclamation. The lake, with a capacity of 847,000 acre-feet, is a major storage reservoir in the Minidoka Project system. It supplies water for all project lands and in addition for about 750,000 acres of private land. The total irrigated area receiving water from this lake, in full or part, produced crops valued in 1947 at $87,600,000.

Jackson Lake Dam, which controls the water level of the river below, also has an important bearing on the nesting of Canada geese. In terms of cash value the geese are insignificant compared to the crop values dependent upon irrigation. General observations on the effect of fluctuating water levels on nesting Canada geese made in the spring of 1946 indicated that the birds fared poorly in this irrigation project.

A survey of geese nesting along the river was accordingly begun in 1947, The objectives being:

1. To determine the nesting population and gather data on the productivity of Canada geese on the upper reaches of the Snake River from Moran to Wilson. (See Figure 1.)
2. To determine the effect, if any, of the regulation of the water flow through the Reclamation Dam at Moran on the nesting of Canada geese.

Financial help for completing the study was obtained through the Jackson Hole Summer Research Program 1947 of the New York Zoological Society, and the Jackson Hole Wildlife Park.

A few facts on yearly activity of geese in this region may prove of interest. The Upper Snake River generally remains ice-free throughout the winter (even though temperatures drop to −40° F. and below). Geese remain along the river throughout the long winter period. In the spring the first observation of migration into the valley was March 13 when a flock of 21 geese was seen. For two successive years paired geese were observed defending nesting territories on April 1, although several feet of snow still covered the ground. By the middle of April geese were incubating; the height of hatching occurred close to the middle of May and was completed by the first of June. Successful parents remained on the river with their broods, while unsuccessful pairs continued defense and nesting behavior with diminishing intensity until about June 1. They then left the river or the lakes. By July 26, the goslings could fly. By August 10, geese were flying in high formations, but the authors believed that most of these were residents. By September 16, geese were congregating in large noisy flocks and the numbers indicated some migration of geese into the area from more northern regions.

STUDY METHODS

The methods used were selected as suitable for an extensive study of a nesting population scattered along 40 miles of a fast, powerful, relatively inaccessible river.

It was felt that a nesting survey could best be accomplished by floating down the river in a five-man rubber raft, taking three days to make each 40-mile trip. Approximately one-third of this distance was covered each day,

and frequent stops were made to locate nests of paired geese. Not all nests were found or even hunted for, but an effort was made to locate every nest site to get an accurate population of paired nesters or potential nesters. Nesting sites fell into three categories: *nests*, *nest sites*, and *general sites*. Geese that had nests or sites defended them; they did not fly until closely approached and usually walked off for some distance and honked their protests. If approached too closely they took off and usually circled and honked at the observer. When such behavior was observed a *nest* was recorded if in addition a nest hollow was found containing eggs or egg remains. A *nest site* was recorded where geese actively defended an area on two or more successive visits, and where shallow nesting hollows were found, but no eggs or egg remains. Such hollows sometimes eventually became the final nest, but some were false, early, or unsuccessful attempts. *General sites* were those defended on two or more successive visits, but where no actual nest or hollow was found. Many of the nests were well concealed, often completely covered with brush, sticks, and sometimes snow. Concealment of nests and limitation of time made it impossible to locate all nests even when they were known to be within a limited area. However, all pairs exhibiting nesting behavior at definite sites were readily located.

A number of associated observations helped to indicate not only the presence of a nest but its exact location; these were:

1. Paired or single birds defending territory and exhibiting nesting behavior.
2. A nearby gravel bar—preferably an island.
3. A raised hummock of vegetation or drift material on or near a gravel bar in proximity to the spot where geese were first seen.
4. An incubating bird, a tuft of down or feathers, or a matting of sticks and brush covering a possible elevated nest site.

While floating the river, relative abundance counts were made of the following birds: geese, ducks, sandhill cranes, pelicans, ravens, and hawks. For example, April 24 trip: ducks, 862; geese, 181; white pelicans, 96; hawks, 55; sandhill cranes, 4. The authors felt that the goose counts might be used for roughly estimating the nesting population if only flushed geese were counted and care was taken to avoid recounts.

WATER LEVELS

During the study, measurements of water levels were obtained at two stations, Moran and Moose. Bureau of Reclamation measurements were used for the former, 1.03 feet being the approximate minimum flow from the lake. Both the Moose and Moran low water marks were taken as constants from which to measure fluctuating levels. The water height at Moose when geese started nesting was 7 inches, at Moran 1.03 feet.

INITIAL LAYING

On April 12, nearly two weeks after the first observed territorial defense, fifteen miles of river were rafted to determine the status of paired geese. Over 50 were counted. The largest flocks, containing 11 and 13, indicated that

some geese had not yet started incubating. Quite a few pairs, however, exhibited nesting behavior and a nest containing 6 eggs was located. These eggs hatched on May 6. Allowing 26–28 days (Kossack, 1947; and Dow, 1943) for incubation and assuming six days for laying prior to incubation would place the initial egg laying on April 1–3. Comparing these goslings of known age with others, it was found that a few geese had started laying close to these same dates. The peak of laying and hatching occurred during relatively short periods—April 18–23, and May 16–21, respectively. Renesting attempts were observed but only two were known to have been successful. By April 24 the majority of geese had eggs, and the authors began the first of three complete trips down the river.

DISTRIBUTION OF NESTS

Nests were distributed along the entire stretch of river, although there was a tendency toward congregation in favorable sites—areas where the river spread over large expanses of gravel, formed numerous islands and channels, and piled drift and debris. Eight nests were located, along a one-mile stretch, six along another mile while four and three were not unusual. The average was about two nests per mile of river (Figure 1).

LOCATION OF NESTS

Nests were located on gravel bars and were situated on elevated clumps of drift or sod behind drift piles. Most sites furnished sufficient range and latitude of view that they could not be readily approached undetected. All locations had enough soil or finely broken drift material to enable the geese to scoop out a shallow saucer-like hollow. Nests in or near scanty clumps of willow and grass vegetation were just above normal summer water level but not above flood level. No nests were in dense cover.

Of 44 nests complete with eggs or in some stage of nest construction, or destruction, 42, or 95 per cent, were located on gravel bar islands varying in size from less than an acre to islands one-half mile long. Two nests were found on the river bank proper. One was in a large Douglas fir tree within an old red-tailed hawk nest approximately 80 feet above the water. Three such tree nests were known in the region and it is possible that periodic spring floods conditioned older birds to seek such sites.

NESTS IN RELATION TO WATER

The low water mark, or the level existing when geese started nesting, was used as a standard for measuring the height of goose nests above the water. The actual rise in water at any one place varied with the number of channels, their width and depth.

The average height of 43 nests (tree nest omitted) above the low water mark was 34.5 inches or roughly three feet. The highest nest was 76 inches above low water and the lowest 6 inches. The average distance of 44 nests from a river channel, small or large, was 43 feet, the maximum distance from water being 150 feet and the minimum 1 foot. Williams and Marshall (1937) found that 63 per cent and 77 per cent of 95 goose nests in the Bear River Marshes were 30 feet from channels and open water, respectively.

NEST LININGS

Twenty-seven of 44 goose nests were lined with down, 7 had eggs but no down. In some cases these nests had been flooded and the down washed away, but in others the geese had only an unlined nesting cavity. Ten cavities had neither eggs nor down and the lack of both was due to varied causes such as flooding in early stages of nest building, or incompleted nesting or renesting attempts. Several nests had a continuous sheet of down which formed a hinged door that could be pulled over the eggs.

AVERAGE CLUTCH

Due to the survey method of study, the data gathered on the size of egg clutches was not extensive. From 17 nests known to have had complete sets of eggs, the average number of eggs was 4.6 per nest. Williams and Marshall (1937) found an average of 4.8 eggs based on counts at 84 nests. Dow (1943) found an average of 5.09 and 5.10 eggs, respectively, from studies of 140 and 215 nests. Our brood counts, made soon after hatching, indicated that 5 eggs per nest would more nearly represent the average clutch than 4.6.

NESTING POPULATION

At the termination of the second trip, 88 nest sites with paired geese had been located and classified as follows:

Nests	44
Nest Sites	24
General Sites	20
Total	88

The two direct counts of geese made in two early trips down the river were approximately the same, 181 and 188. Any one count, divided by two to give pairs, approximated the total number of nest sites recorded. These counts would indicate a population of between 90 and 94 pairs of geese as compared to 88 pairs of geese actually defending nests or nest sites. For a rapid survey of river populations it is possible that a single count or a series of counts will give an accurate population figure and even an accurate nesting population without recourse to locating nests. The fact that the direct count closely approached the number of paired geese determined from location of nest sites indicated that the river population comprised few unpaired birds and that the total of 88 pairs of nesting geese located during a period of one month on the 40-mile stretch of the Snake River was close to the total nesting population.

Observations indicated that this same density (an average of 2.2 pairs per mile) of nesting geese extended up the Snake River into Yellowstone Park as well as down the river for an undetermined distance. The larger tributary streams in the Jackson Hole area likewise served as breeding areas but with a somewhat lower nesting density.

GOSLING COUNTS

Through May 21, 82 young were known to have hatched with some eggs still being incubated. Through July 11, the count was 21 separate broods totalling 94 goslings. The broods varied from one to seven with an average of 4.5 goslings. At that time the immatures could still be distinguished from adults by the duskier white cheek patch (adults had a much more brilliant and sharply outlined patch) and by their general

duskier and more brownish cast. On July 26 another float trip was made and the goslings counted. By this date they could fly, were consequently more difficult to approach and could not always be distinguished from adults. Some geese were still in family groups but the majority were in flocks, the largest of which was 40. Thirty-three goslings were counted in family groups and 105 geese in mixed flocks. Of these latter the authors calculated that on a basis of 4.5 goslings to a pair of adults, there were approximately 73 goslings represented in the mixed flocks. The attempted separation counts were in line with this figure. The total of 106 goslings was felt to more nearly approach the actual number of goslings on this stretch of river than any of the previous counts. Approximately 106 goslings reached the early flying stage (about six weeks).

PRODUCTIVITY

It would therefore seem that 88 pairs of nesting geese produced 106 goslings, or 1.2 goslings per pair, or less than one per adult. The largest clutch of eggs found was seven. Using this as the maximum potential of the species in this region, the potential productivity would be 616 goslings. On a basis of an average clutch of 5, the potential productivity would be 440. Both figures are considerably higher than the actual observed productivity of 106.

MORTALITY FACTORS

Some of the principal mortality factors which brought about this discrepancy between actual and potential productivity were flooding, predation, and unfavorable weather conditions combined with the first two factors. Observation indicated that these factors caused the greatest mortality prior to hatching. The survival of goslings appeared very high. Williams and Marshall (1938) likewise found that mortality factors in goslings were negligible.

SWIFT WATER

The authors suspected that high swift water might cause juvenile mortality by separating the goslings from their parents. Broods separated and dispersed by the rubber raft were watched and rechecked as to numbers. In such instances young geese followed the raft for several miles and on occasion actually appeared to mistake the raft for their parents. The goslings were too young to fly, yet could not swim against the swift current. There was, however, no indication that the swift water, although dispersing broods and altering territories, was a mortality factor in young geese. The adults usually rounded up their offspring and remained in the new downstream territory. It is of interest that throughout the breeding season, intra-specific strife was singularly lacking. On numerous occasions geese grouped together in apparent defence of a raven-destroyed nest. When undisturbed, the family units stayed in the vicinity of their nesting sites for long periods. Many broods eventually mixed with other broods. There was a general tendency for families to drift gradually downstream and to congregate at wide island-studded expanses where the divided current was less swift.

BIRD PREDATORS

On each trip, hawk and eagle nests or

nesting territories within one-fourth mile of either river bank were located and plotted on a map. Territories consisted of an area where these birds exhibited nesting behavior, indicating a nearby nest. A total of 36 nesting pairs was found: 13 red-tailed hawks, 18 sparrow hawks, 6 Swainson's hawks, 8 sharp-shinned hawks, 4 Cooper's hawks, 1 bald eagle. This was not the complete nesting bird-predator population along this stretch of river. The population surveyed in this manner was approximately 1 pair per mile of river or nearly 2 pairs per square mile of nesting area, and did not include owls. Much more intensive studies on predator populations in this region (unpublished) indicated a hawk nesting population of 2.75 pairs to the square mile. The hawk population, however, had no observed effect on the mortality of goose broods. The most likely bird-predator was the bald eagle. Eight goose nests were located within a distance of one-half mile of this eyrie, yet no gosling remains were found at the nest and the geese apparently did not fear the eagles. Mortality from ravens was a different story.

Raven nests and broods along the river were plotted on each trip. Eighteen nests or broods were located. They were fairly evenly distributed and sufficiently near the river that both adults and young ravens could hunt the river flats. Ravens were observed ranging several miles from their nests so that 18 pairs could forage very efficiently over the entire 40-mile stretch of river. Early in the study it became evident that ravens were a factor in the destruction of goose eggs. None was actually caught in the act of destroying eggs, but there was sufficient indirect evidence to incriminate them. The following description of a raven-destroyed nest was more or less typical of all so classed: the nest down was scattered, egg shell remnants were strewn with the down to a distance of 10 or 15 feet. Shell fragments were found on and beneath a nearby perch five feet above the ground with raven excrement beneath. Such a perch could not have been used by any terrestrial predator. The usual bloody membranes of hatched eggs were lacking. Adult ravens were seen nearby. This picture, with slight modifications, was similar at all nests where ravens were suspected of the destruction. Ravens frequently flew low over the wide areas where geese congregated to nest. In such places they foraged, combing back and forth over the channels and island bars. On other occasions, when geese were honking, the noise soon brought ravens to the spot. Usually they flew past while looking the situation over but quite possibly they returned later, perhaps in a manner similar to the following observation:

Soon after sunrise two geese were heard honking noisily about one-fourth mile from the observer, who was hidden in a spruce stand. In a few minutes they passed overhead on their way to feeding grounds. Two ravens then immediately left the woods, flew in the direction from which the geese had come, and quartered the nesting area, flying very low.

This particular goose nest had already been destroyed by ravens and the geese had started a renesting attempt. These geese had been previously observed flying off together leaving the nest hid-

den but unattended; and they usually honked noisily as they took off. The authors feel that their noisy behavior at the nest and their habit of leaving it unattended were the principal causes leading to destruction by ravens. It appeared that the egg-laying period prior to incubation was the time when a nest was most likely to be left unattended. Thirteen nests gave evidence of having been destroyed by ravens. Coyote tracks were seen in the vicinity of two of the destroyed nests but there was not sufficient evidence to attribute their destruction to these mammals. Sooter (1946) says that "the coyote proved to be a major predator on the Refuge [Malheur National Wildlife Refuge] being equalled only by the raven." Coyotes were not numerous along the Snake River. None was seen but a few were heard in the course of raft trips. An area of 12 square miles (3×4 mi.) embracing both sides of the river at Moose had 2 denning pairs, the dens being located on opposite extremities of this area.

FLOODING

By May 21, 9 nests were known to have been destroyed by flooding. This early flood condition was caused by increased tributary flow as a result of melting snow. On May 3, with the Moran river gauge reading 1.23, the water level at Moose had risen 2 feet 6 inches and by May 11 to 3 feet 2 inches above the low water mark. On May 22 the discharge of water from Jackson Lake was 3.71 feet and on May 25, when Jackson Lake filled, the natural flow was allowed to spill out. Not until this time had water from the dam played a role in flooding of nests. This release, however, raised the water level at Moran from 1.03 feet, or low water, to 6.84 feet, and the level at Moose to 5 feet above the low water mark.

Below Moose still other tributaries, the largest of which is the Gros Ventre, poured additional flood water into the Snake, thus increasing flood conditions in the lower part of the river. The authors estimated that nearly all the goose eggs would have hatched by June 1. This high water during the last week of nesting, however, accounted for an appreciable but unmeasurable destruction. On May 28 the water levels at Moran and Moose were approximately 8 feet and 5 feet 8 inches, respectively, above the low water level. As mentioned before, the average height of goose nests above low water mark was 3 feet. The flooding of nests, however, was not so great as these figures would indicate because the geese had selected the wide channel-cut stretches of river bottom where flood waters were dispersed so successfully that the actual rise of water in some channels was considerably less than at the measurement stations.

Information on nest successes and failures was as follows:

Successful nests	21
Destroyed by ravens	13
Destroyed by flooding	9
Unknown destruction	45

Most of the nests falling under "unknown destruction" could probably be attributed to flooding and ravens, with perhaps a few to coyotes, a few to nest site competition (unobserved), and others to indifference, infertility, and other characteristics of the geese themselves. Nests assumed to be destroyed by ravens were easier to locate than those that had been flooded out, and

this fact is somewhat responsible for the higher mortality figure. It is also quite possible that some nests destroyed by ravens had been abandoned before destruction. After the highest water there was no way to determine how many nests still with eggs were destroyed and at how many of them the eggs had hatched prior to high water. The authors estimate that perhaps 25 per cent were destroyed by flooding. However, flooding as a mortality factor can be much greater than the authors found in the spring of 1947. For example, in 1946 only 12 goslings were counted along a 25-mile stretch of the river, whereas in 1947, 33 were counted at a corresponding date. Considerably fewer goslings were seen in 1946 along the entire stretch of river studied. Table 1, showing comparative water release levels at Moran for the two years in conjunction with the nesting activity of geese, points to a possible reason for low gosling productivity in 1946. These water level figures also indicate the nest destruction that could result from a water control policy inconsiderate of the vulnerable periods in the nesting cycle of Canada geese.

In 1947 the period of nest site selection ranged between the last week of March and the last of April. The peak of nest site selection occurred during a

TABLE 1.—GOOSE ACTIVITY DATES AND ACCOMPANYING WATER LEVELS FOR 1946–47 ON THE UPPER SNAKE RIVER, WYOMING

Goose Nesting Activity—1947	1946 Water Levels at Moran	Comments	1947 Water Levels at Moran	Comments
Month prior to nest selection (March)	Max. 5.90 Min. 3.66			
Earliest nest site selection March 25–April 1	Av. 5.12	Sites probably selected on high ground	Min. Flow 1.05 April 1	Sites selected on low gravel bars
Ht. of nest site selection (April 10–18)	Av. .97	Majority of nest sites probably selected on low ground	Min. flow to May 22	Sites selected on low gravel bars
1st egg laying (April 1)	5.08	Few in numbers		
Period of maxinum egg laying (April 18–23)	Av. .87	Egg laying successful		Nesting activities unaffected by water flow
Incubation and continued egg laying (April 23) Approximate 5′ rise in water	5.45	Flood mortality possibly very high at end of maximum egg laying period		
First hatching (May 6)	.43	Minimum flow		1st hatching successfully completed
Peak of hatching (May 16–21)	Av. .41	Minimum flow No flood damage		Peak of hatching successfully passed
May 25			6.84	Lake filled, natural flow, destruction of some nests still containing eggs. First discharge May 22 of 3.71′
May 28 some incubation	4.00		9.21	
May 29 some incubation	7.70	Lake filled, natural flow	8.30	
Nesting completed (June 1)	6.03		8.26	Nesting completed
Goslings on river (June 10)	8.25		9.28	Little or no gosling mortality due to high water

short period prior to the height of egg laying and in most instances could not have occurred earlier since the sites were covered by 2 to 3 feet of snow. The peak of laying was between April 18 and 23. Site selection was at a maximum during the preceding week to ten days (April 10–18). The earliest nesting of a few birds was on April 1–3 and those geese were in the lower stretch of the river. The difference in altitude between these lower nests and the uppermost ones was as much as 500 feet. Milder weather and less snowfall was typical of the lower region. If the water levels for 1946 (Table 1) are checked with these 1947 dates, it is seen that during March the maximum and minimum river heights were 5.90 feet and 3.66 feet, respectively. On April 1, the river height rose to 5.08 feet and dropped to a more or less minimum flow thereafter until April 23. One day of high water, 4.83 feet, intervened on April 9. The few earliest nesters, influenced by the relatively high March flow, probably nested in high places where snow-free sites were available. However, the period between April 1 and 23 was one of low water save for one day. This period embraced not only that of maximum nest site selection but also of maximum egg laying. It is reasonable to assume that many sites were selected low and close to water. A drop in water level from April 2 to April 23 would have bared gravel bars previously covered by water. These low bare gravel bars would be attractive as nest sites in comparison to the surrounding environment of deep snow. This period of low-water, site-selection, and egg-laying was followed on April 23 by a single flow of 5.45 feet. Figures on the location of nests in 1947 indicated a tendency for geese to nest both low and close to the water. Assuming that the average height of nests above the low water mark was 3 feet (as found in 1947) it is possible that with normal tributary contribution as well, close to 50 per cent of the nests could have been flooded out. In addition, if weather conditions such as an early or prolonged thaw accompanied this man-controlled rise in water, the actual flood conditions could have been even greater. This was actually the case in 1946 and the authors feel that the low goose productivity of that year resulted from the flood conditions and fluctuations of the Snake River during the nesting period.

In 1947 the natural runoff from thawing snows and spring storms accounted for flood loss in nests as late as May 22. Thereafter the discharge of water from Jackson Lake Dam flooded any nests that were still in the incubation stage. Fortunately the peak of hatching had passed. A week later, the same water rise (1.03 feet to 6.84 feet) would have done no harm.

The authors do not wish to imply that Jackson Lake Dam and the accompanying control of its water reservoir have increased nesting flood mortality of geese over that which existed prior to the dam. They do, however, want to point out that the dam has made possible a control of flood waters previously not manageable. Water could be discharged from Jackson Lake so as to cause practically no flood loss; on the other hand, it could be released in such a manner that it would destroy an estimated 80 to 90 per cent of the goose nests.

MANAGEMENT SUGGESTIONS

Two practices which can do most to maintain a nesting goose population and increase its productivity in this area are:

1. The continued preservation of nesting and feeding grounds.

2. The encouragement of a policy that as far as is practical attempts to regulate water levels beneficially during the breeding season of Canada geese.

The first will in large part be taken care of automatically if the Jackson Hole National Monument remains intact as created by President Roosevelt or if this land remains under government control. Fifty of the 88 pairs of geese nesting along the 40 mile stretch of river were within the Jackson Hole National Monument. Numerous lakes in the Monument offer havens of safety as well as feeding areas for both resident and migrating geese. This is particularly true of the northern end of Jackson Lake.

As to the second factor, the present water regulation policy governing the flow through Jackson Lake Dam considers: first, the water users; second, flood control.

The Bureau of Reclamation in its multiple tasks of conserving water, protecting dams and reservoirs from floods, and distributing water as required by project interests is not unmindful of wildlife demands. At times it is necessarily working with many variable and uncontrollable factors. In view of the importance of this area to nesting Canada geese, heretofore unsuspected, it is hoped that the Bureau can fit the needs of the Canada geese into its multiple water control plans.

Once the dam fills, all water control is automatically lost. Severe property damage has resulted in the past from a lack of control during high tributary runoff. In early years this was unavoidable; however, the surveys of snow depth made over the years by the Bureau of Reclamation show that it is now possible to determine the amount of runoff and to forecast, with an accuracy of 80 per cent, the volume of water to flow into the dam. Since 1917, the reservoir has filled to capacity in 19 of 31 years. Better winter and spring water control could help the goose situation without jeopardizing the later filling of the dam. A safe margin of reserve is necessary in the event of an abnormal spring and too much water cannot be released until April 15 when the last snow survey is taken and final data are available for forecast. Within this limitation, it would appear beneficial to release a variable but predetermined amount of water from the dam during the winter months to prevent early filling of the lake. High water during March and the first half of April could then be followed by a low and non-fluctuating water flow until the first of June. This was nearly achieved in 1947. Such control would react favorably toward nesting geese in two ways: it would cause them to initiate nest construction at a generally higher level, thus providing a larger margin of safety in case of a rise in the water due to tributary flooding, and it would delay the filling of Jackson Lake Dam until the completion of hatching.

Such control would not cause stress to Idaho farmers, particularly in view of the fact that the lower Palisade Dam and Reservoir below Alpine will, when completed, ease the demand on the

Jackson Lake Reservoir. Perhaps the best way of attaining this control would be to take approximately 400,000 acre feet of firm storage space in Jackson Lake and transfer it to Palisade Reservoir. This would make available space in Jackson Lake Reservoir for flood control. It would help remedy spring flood conditions of the Snake River in and below Jackson Hole and would go far toward putting a stop to contemplated plans of dyking and channelling this picturesque river in the lower part of the region studied. Over a period of years water control cognizant of wildlife needs as well as the needs of irrigation and flood control might well double the present Canada Goose productivity in this area.

SUMMARY

Geese in the Jackson Hole area during 1947 started nesting on or about April 1 with the peak of laying and hatching between April 18–23, and May 16–21, respectively. Nesting was completed by June 1.

Nests were distributed over a 40-mile stretch of the Snake River averaging about 2 per mile with marked concentrations in the wide channel-split expanses of river bottom.

Ninety-five per cent of the nests were located on islands and most sites were elevated piles of drift or sod situated on or beside gravel bars.

Of 43 nests above the low water mark, the average height was 34.5 inches, the maximum 76 inches, and the minimum 6 inches.

The average distance of 43 nests from water was 43 feet, the maximum 150 feet, and the minimum 1 foot.

The average clutch determined from only 17 nests was 4.6 eggs per nest; 5 was thought to be a more representative figure.

Eighty-eight pairs of geese either nesting or exhibiting territorial behavior were located, and this was considered very close to the actual nesting population.

Counts during two float trips down the Snake River indicated between 90 and 94 pairs of geese.

The similarity in results of the two methods indicated that along a river a direct count of paired geese exhibiting nesting behavior will give a rapid and accurate picture of a potential nesting population without recourse to the more time-consuming task of locating nests. It was felt that there were few unpaired geese among the population.

The density of 2.2 pairs of nesting geese per mile of river studied appeared to extend both up and down the Snake River for considerable distances and to apply to the larger tributary streams as well.

A count on 21 separate broods gave an average of 4.5 goslings per brood.

One hundred and six goslings were known to have reached the flying stage (about six weeks). This amounted to a productivity of 1.2 goslings per pair on the basis of 88 pairs.

Mortality factors were most active before and during incubation. Little or no gosling mortality was found; 21 nests were known to have been successful, 13 were destroyed by ravens, 9 were definitely flooded, and 45 were classified as destroyed by unknown causes but most of the loss was believed to have been due to flooding and to raven predation.

Twenty-five per cent of the nests

were estimated to have been destroyed by flooding. Flooding has and could cause much greater losses. Flood mortality can to a large extent be eliminated by water control.

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FOOD HABITS IN RELATION TO BLACK DUCK MANAGEMENT IN MAINE[1]

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INTRODUCTION

The black duck (*Anas rubripes*) is the most important species of waterfowl in eastern Canada and in the Atlantic Coastal states south to Chesapeake Bay. During recent years its numbers have declined somewhat alarmingly in parts of its range as have those of most other ducks and geese. Under present-day hunting pressure, perpetuation of wildfowling as a sport, which was seriously threatened in the 1930's, is again considered by many ornithologists and wildlife technicians as being in a rather critical condition. Programs for the management of waterfowl have been in operation in various parts of North America for the past 15 years and a great deal has been learned, especially as regards the maintenance of suitable habitat conditions in the west and midwest. But in the northeast published information is still lacking for the management of waterfowl in general and for the black duck in particular.

In 1938 a waterfowl research program was initiated by the Maine Cooperative Wildlife Research Unit in an attempt to obtain as much information as possible on the distribution, migration, and habitat requirements of Maine's waterfowl resources. Among other phases of the project receiving detailed study has been food habits, and the present paper gives the results obtained to date as applied to the black duck.

The need for such a study in this region has been apparent for several years. One of the techniques of waterfowl management that has been widely applied has been the introduction of

[1] A contribution from the Maine Cooperative Wildlife Research Unit—Maine Department of Inland Fisheries and Game, University of Maine, Wildlife Management Institute, and U. S. Fish and Wildlife Service, cooperating.

food plants in water areas having a deficiency of natural foods or where such a deficiency was believed to exist. These measures have a real value in improving marsh habitats, especially on refuges or managed areas, but it is necessary to have a knowledge of specific and local waterfowl requirements before such work can be carried out efficiently. In recent years many outstanding studies on waterfowl food habits have been conducted in various parts of the United States and Canada. These publications are either of a general nature, however, or else are based largely on data accumulated in the west, mid-west, or south, and apply only slightly to the black duck. Specific publications on the food of the black duck are exceedingly few. Most outstanding is one by McAtee (1918). Unfortunately much of McAtee's information is not applicable to northern New England, and such of it that is, was gathered primarily in coastal marshes more than 30 years ago. Habitat conditions have changed considerably since that time. The only recent study in the northeast is that of Addy (1945), which discusses fall and winter foods in coastal Massachusetts.

Experience has shown with increasing clarity that local food studies are necessary before effective management based on planting programs can be carried out. Some of the duck food plants that are recognized by game technicians as being of paramount importance in much of North America do not even occur in Maine and will not grow when they have been introduced. In the interior of northern New England, cold waters, and those that are either acid or only slightly alkaline, prevail, and constitute a decided contrast from those in most of the country.

Even though the present study has been carried out in Maine, it is believed that the results may be applied in other parts of northern New England, in northern New York, and in sections of southeastern Canada. Data cover the period 1938 to 1946 inclusive. All seasons of the year and all sections of Maine are represented, although obviously not in equal proportions.

Two methods of study were used—direct observations of feeding and feeding habits, and stomach analysis. Data from the latter method is of course much more accurate and forms the basis for this paper, although supplementary information from observations will be given when they appear relevant. The largest number of specimens for analysis was obtained during the hunting season. A selected group of game wardens and sportsmen, whose accuracy could be relied upon in recording data relative to the taking of the birds, assisted the technical workers a great deal and enabled a large number of stomachs to be examined. To obtain data on food habits throughout other seasons of the year, specimens were obtained in a variety of ways. Some were found killed by predators, some were killed illegally and eventually turned over to the technicians by the State or Federal wardens, and some were taken by the writer and his co-workers under a scientific collecting permit; most of the spring birds were caught in traps during the muskrat trapping season, which usually runs from April 1 to May 10.

Stomachs were analyzed under the supervision of the writer in the laboratory of the Maine Cooperative Wildlife

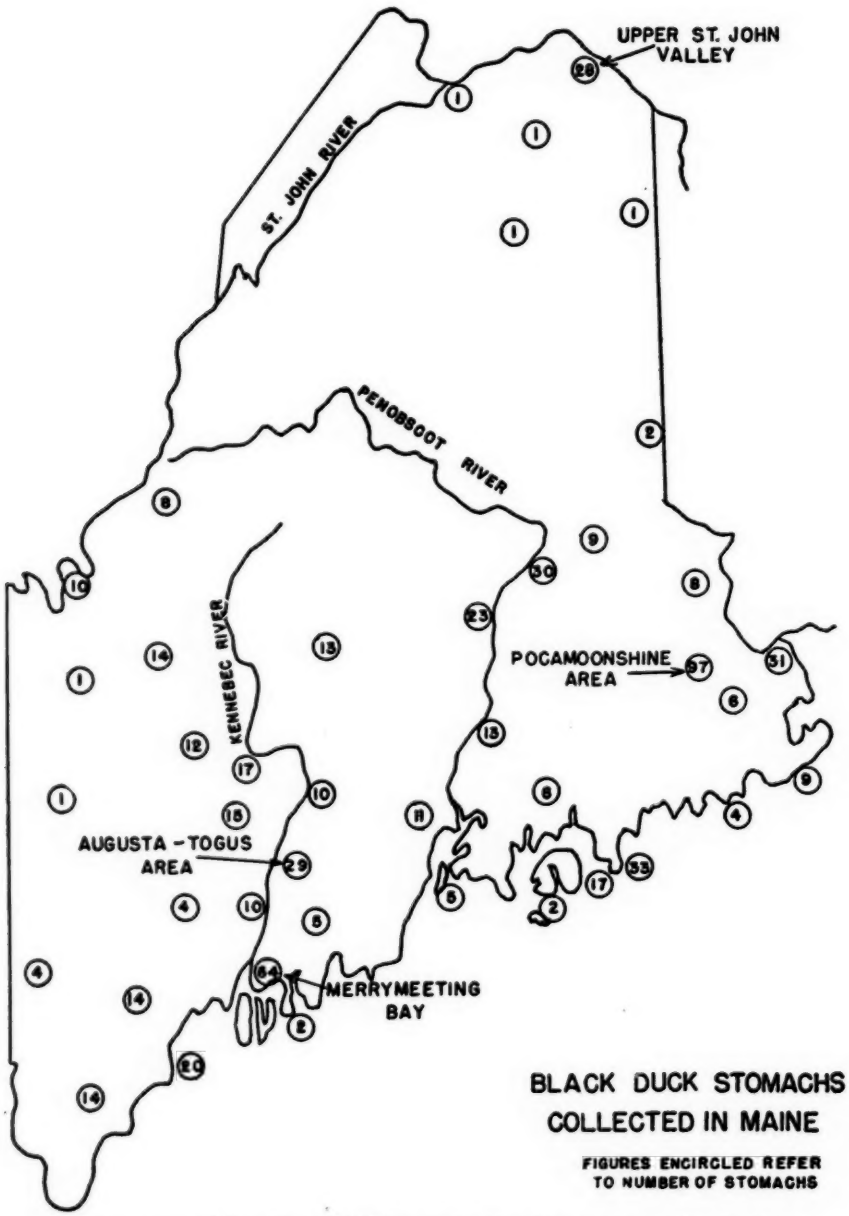

FIG. 1.—Map of the State of Maine indicating the locations of collections included in this study.

Research Unit. The services of several authorities in various biological fields at the University of Maine were available for assistance in identifiction of food items and the facilities of the Patuxent Research Laboratory of the

U. S. Fish and Wildlife Service served as a source of final checking of unknown material. Analysis was of dry material by the "percentage-by-bulk" method, as currently practised by the U. S. Fish and Wildlife Service. Separated food items were measured to the nearest tenth of a cubic centimeter. Tabulation was by averaging individual percentages with each stomach being considered as a unit (those which were estimated as being less than $\frac{1}{8}$ full of food—exclusive of grit—were discarded), the accepted technique used by most wildlife food analysts when working with waterfowl stomachs.

The black duck food study has been under the supervision of the writer, but many individuals and agencies have contributed materially to it. It was initated by the Maine Unit in 1938. From 1939 to 1943 it was a joint project of the Unit and of the Federal Aid Division of the State Department of Inland Fisheries and Game.[2] From 1944 to 1946 it was carried out solely by the Maine Unit. Special thanks are due to Commissioner George J. Stobie, to the former Federal Aid Coordinator—the late Joseph S. Stickney, and to the present Federal Aid Coordinator—Merwin A. Marston, for permitting their department's share of the data to be published with that of the Unit; and for the financial assistance given by their department.

[2] This work was undertaken with Federal Aid to Wildlife Restoration funds under Project Number 1-R. Subsequent assistance was also rendered by the Maine Federal Aid Division through financial help to the Wildlife Society in defraying part of the publication costs. This contribution was provided under Project Number 1-R.

The appreciation of the writer is herewith expressed to Jay S. Gashwiler, Assistant Leader of the Maine Unit, who collected many specimens and recorded numerous observations of feeding; much of the actual analysis work was carried out by him, both during his employment with the Maine Unit and with the State. Other technical workers who assisted in collecting specimens or in analizing stomachs are Joel W. Marsh, Edward G. Wellein, Stephen E. Powell and Nathan Fellows, Jr. of of the Maine Department of Inland Fisheries and Game; also Charles P. Brown, Malcolm W. Coulter, and Leslie L. Glasgow of the Maine Cooperative Wildlife Research Unit. Thanks for assistance in identification of food items are due F. H. Steinmetz, E. C.Ogden, Fay Hyland and C. O. Dirks of the Department of Botany, and to B. R. Speicher, J. Fuller, and G. P. Cooper of the Department of Zoology, University of Maine; also to Clarence Cottam Arnold Nelson, F. H. Uhler, A. C. Martin, Neil Hotchkiss, and A. H. Trowbridge of the U. S. Fish and Wildlife Service. For cooperation in obtaining specimens, appreciation is expressed to Commissioner Stobie and many of the wardens of the Maine Department of Inland Fisheries and Game—especially Lloyd Clark, Raymond Morse, Roy Gray, Charles Harriman, Paul Hanscom, Lyle Smith, Clinton Barrett, Cassius Austin, and the late Levi Dow.

A large number of sportsmen have been most helpful in the study and this assistance is appreciated. To one in particular, John M. Dudley, the writer is deeply grateful for his interest and help. The large series of stomachs from the Pocamoonshine-Crawford area were

collected mainly by Dudley. He also assisted the writer in the vegetative survey and in the water level study carried out on that area.

TYPES OF HABITAT

The waterfowl habitat in Maine may be roughly classified into three broad types: (1) inland fresh water; (2) inland tide water; (3) coastal water. All are used by black ducks under certain conditions and at particular seasons of the year. Since considerable differences in the food available for the birds exist in these three types, collections were made in each and separate tabulations were prepared.

Inland fresh water. All ponds, lakes, streams, and rivers in the interior of the State which contain strictly fresh water and which are not affected by tides are placed in this category. This type is the most extensive of the three and is the one most widely used during late spring, summer, and early fall. The majority of the breeding birds in Maine are found on waters of this type.

Inland tide water. The tidal portions of rivers and streams are placed under this heading, as are a few sheltered bays having fresh water inlets. All such waters are subject to tidal fluctuations but most of them contain a low percentage of salinity. Some, such as the upper tidal portions of the Penobscot River (Bangor is the head of tide) and the Kennebec River (Augusta is the head of tide) contain so little sea water as to support an abundance of strictly fresh water plants. Merrymeeting Bay —a famed waterfowl concentration place—is in this classification; although subject to considerable tidal influence, two large rivers, four small rivers, and numerous brooks and streams flow into Merrymeeting Bay so that the water is largely fresh except in the lower part of the Bay.

This type of habitat is quite extensively used by black ducks during the spring migration but is of most value during the late summer and fall, many birds remaining until forced out by freezing weather. Only a very few blacks use these waters for breeding purposes. Some of the State's most heavily hunted marshes come under the inland tide water classification.

Coastal water. Strictly open coastal bays, salt marshes, and salt ponds are placed in this type. Used sparingly during the warm seasons of the year, the coastal waters are of most importance in late fall and throughout the winter.

SELECTION OF SEASONS

In grouping black duck foods by seasons a slight departure was made from a strict observance of the calendar in that *Winter* was considered as starting December 1. In Maine, by that date, winter has truly set in (except in very unusual years) as far as waterfowl are concerned. The fresh waters are frozen as are many of the inland tide waters. Even those interior waters which may be still ice-free are practically forsaken by black ducks. Only the coastal waters are used by the blacks after December 1 except in very limited numbers. If food data, gathered in early December, had been grouped with fall food certain items in the diet would not have been shown in proper proportions. Aside from this one arbitrary distinction, the calendar was adhered to.

PRESENTATION OF DATA

In the following pages, the tabulated food data are grouped by seasons. The material is broken down by habitat types for the fall and winter seasons when collections covered more than one type. Spring and summer food is discussed largely for the inland fresh water type since collections were made only in these waters—this being the most important habitat for breeding black ducks. Summer food is further broken down into that of adults (including a few young not quite at the flying age) and that of the downy young. This distinction is made since an examination of the data revealed significant differences in the food of downy young. After the ducklings reach the age of two or three weeks their food differs very little from that of the adults regardless of whether or not they are able to fly.

Tabulated data are only those obtained during the present study. However, through the courtesy of the U. S. Fish and Wildlife Service, photostat copies of the original stomach analysis cards of Maine black ducks which were used by McAtee in his 1918 publication were made available to the author. These, when grouped, show considerable differences in food of Maine ducks from McAtee's over-all tabulation. In the present publication some of McAtee's data are discussed briefly in connection with coastal waters, primarily to show changes in black duck foods in Maine after a 25 to 30 year interval.

In addition to the data from the stomach examinations, information obtained from visual observations are discussed from time to time in the text; also a few miscellaneous records are given for individual stomachs which might be of unusual interest.

FALL FOOD

INLAND FRESH WATER—366 STOMACHS

The largest number of specimens was classified under this subdivision. Data were well distributed throughout late September, October, and November, and all parts of Maine were represented except the extreme northwestern part of the State, which is of slight importance to waterfowl other than mergansers. Efforts were made to have adequate collections in all four of the major flight lanes through Maine which lie within the valleys of the following rivers—St. John, St. Croix, Penobscot, and Kennebec. Table 1 shows the tabulated results of the stomach analysis.

It may be seen that black ducks in the interior of Maine feed heavily on vegetable foods, the most important of which are various plants in the bulrush family. Two species are outstanding—a submerged plant, water bulrush (*Scirpus subterminalis*), and an emergent plant, Torrey's three-square bulrush (*S. torreyi*); between them they constituted over 30 per cent of the entire fall food of the birds examined. A few seeds were consumed, especially of the three-square bulrush, but more than nine-tenths of the food of these two plants consisted of tubers and other subterranean structures. Each is common throughout Maine, especially water bulrush. This plant grows abundantly in rivers and streams with considerable current or in nearly stagnant ponds; it thrives in water from a few inches to six

TABLE 1.*—FALL FOOD OF BLACK DUCKS FROM INLAND FRESH WATER, 366 STOMACHS

VEGETABLE FOOD	Percentage of total	Percentage of total
Cyperaceae		*38.4*
Water bulrush (*Scirpus subterminalis*)	*21.5*	
Torrey's three-square bulrush (*S. torreyi*)	*9.6*	
Sedge (*Carex* sp.)	*2.9*	
Bulrush (*Scirpus* sp.)	*1.1*	
Beak rush (*Rynchospora* sp.)	.7	
Triangle spike rush (*Eleocharis robbinsii*)	.7	
Spike rush (*Eleocharis* sp.)	.6	
Spike rush (*E. palustris*)	.4	
Large three-square bulrush (*Scirpus americanus*)	.2	
Sedge (*Carex crinita*)**	.2	
Three-way sedge (*Dulichium arundinaceum*)	.2	
Wool grass (*Scirpus cyperinus*)	.1	
Spike rush (*Eleocharis acicularis*)	.1	
Twig rush (*Cladium mariscoides*)	.1	
River bulrush (*Scirpus fluviatilis*)	Trace	
Hard-stemmed bulrush (*S. acutus*)	Trace	
Bulrush (*S. smithii*)	Trace	
Bulrush (*S. paludosus*)	Trace	
Sparganiaceae		*11.6*
Bur reed (*Sparganium* sp., chiefly *S. chlorocarpum*)	*11.5*	
Bur reed (*S. fluctuans*)	.1	
Bur reed (*S. minimum*)	Trace	
Najadaceae		*8.9*
Floating-leaved pondweed (*Potamogeton natans*)	*5.1*	
Pondweed (*Potamogeton* sp.)	*1.5*	
Celery-leaved pondweed (*P. epihydrus*)	.8	
Pondweed (*P. pusillus*)***	.7	
Pondweed (*P. perfoliatus*)	.4	
Bushy pondweed (*Najas* sp., mostly *N. flexilis*)	.3	
Variable pondweed (*Potamogeton gramineus*)	.1	
Pondweed (*P. spirillus*)	Trace	
Horned pondweed (*Zannichellia palustris*)	Trace	
Gramineae (except *Hordeum* and *Avena*)		*5.9*
Wild rice (*Zizania aquatica*)	*4.2*	
Rice cut-grass (*Leersia oryzoides*)	*1.3*	
Manna grass (*Glyceria borealis*)	.3	
Manna grass (*G. canadensis*)	.2	
Reed canary grass (*Phalaris arundinacea*)	Trace	
Alismaceae		*3.2*
Arrow-head (*Sagittaria latifolia*)	*1.4*	
Arrow-head (*Sagittaria* sp.)	*1.0*	
Arrow-head (*S. graminea*)	.5	
Arrow-head (*S. cuneata*)	.3	
Domestic Grains		*2.6*
Barley (*Hordeum* sp.)	*1.1*	
Buckwheat (*Fagopyrum esculentum*)	.7	
Oats (*Avena* sp.)	.8	
Polygonaceae (except *Fagopyrum*)		*2.6*
Smartweed (*Polygonum* sp.)	*1.0*	
Water pepper (*P. hydropiper*)	.9	
*Water smartweed (*P. natans*)	.4	
Long-seeded smartweed (*P. pennsylvanicum*)	.3	
Smartweed (*P. careyi*)	Trace	
Smartweed (*P. persicaria*)	Trace	
Nymphaeaceae		*1.2*
Water shield (*Brasenia schreberi*)	.6	
*Yellow water lily (*Nuphar* sp.)	.6	
*White water lily (*Nymphaea odorata*)	Trace	

TABLE 1—(*Continued*)

	Percentage of total	Percentage of total
Miscellaneous Vegetable Food		9.7
Pickerel weed (*Pontederia cordata*)	.7	
Coontail (*Ceratophyllum demersum*)	.6	
Dogwood (*Cornus* sp.)	.6	
Winterberry (*Ilex verticillata*)	.4	
Cherry (*Prunus* sp.)	.3	
Blackberry or raspberry (*Rubus* sp.)	.3	
Horsetail (*Equisetum* sp.)	.3	
Large cranberry (*Vaccinium macrocarpon*)	.2	
Mermaid weed (*Proserpinaca palustris*)	.2	
Buckbean (*Menyanthes trifoliata*)	.2	
Wild celery (*Vallisneria spiralis*)	.2	
Beggar Tick (*Bidens* sp.)	.1	
Alder (*Alnus* sp.)	.1	
Gray birch (*Betula populifolia*)	.1	
Miscellaneous plant material	.1	
Unidentified plant material	5.3	
Total Vegetable Food		84.1
ANIMAL FOOD		
Insecta		8.9
Dragon-fly (Anisoptera)	3.8	
Miscellaneous beetles (Coleoptera)	.8	
Miscellaneous moths (Noctuidae)	.8	
Caddice-fly (Trichoptera)	.8	
Dragon-fly or damsel-fly (Odonata)	.4	
Spittle-insect (Cercopidae)	.2	
Diving-beetle (Dytiscidae)	.1	
Giant water-bug (Belostomatidae)	.1	
Water-boatman (Corixidae)	.1	
Miscellaneous insects	1.8	
Gastropoda		5.0
Miscellaneous snails	4.0	
Snail (*Campeloma decisum*)	.4	
Snail (*Amnicola* sp.)	.2	
Wheel snail (*Helisoma* sp.)	.2	
Wheel snail (*Planorbis* sp.)	.2	
Pelecypoda		1.3
Miscellaneous bivalves	.6	
Pill clam (*Pisidium* sp.)	.3	
Fresh-water clam (*Anodonta* sp.)	.2	
Pill clam (*Musculium* sp.)	.1	
Pill clam (*Sphaerium* sp.)	.1	
Miscellaneous Animal Food		.7
Spider (Arachnida)	.4	
Fresh-water shrimp (*Hyalella* sp.)	.1	
Miscellaneous mollusks	.1	
Miscellaneous fish remains	.1	
Total Animal Food		15.9
Grand Total		100.0

* The scientific nomenclature used is that of the following authorities: for insects, Comstock (1940); for invertebrate animals, Pratt (1935); for most aquatic plants, Hotchkiss (1936); for other plants, Gray's Manual (1908). In certain cases where the names of Hotchkiss do not conform to present usage, Fassett (1940) has been referred to—such plant names are preceded by an asterisk. A few other variations are explained in footnotes.

** From Gray's Manual—not listed by Hotchkiss or Fassett.

*** This plant is probably the one now called *P. berchtoldi*, although it may be in part the species formerly called *P. panormitanus* (see explanation in Rhodora, 42: 246).

TABLE 2.—FALL FOOD OF BLACK DUCKS FROM INLAND TIDE WATER, 92 STOMACHS

	Percentage of total	Percentage of total
VEGETABLE FOOD		
Gramineae		50.3
Wild rice (*Zizania aquatica*)	50.3	
Cyperaceae		17.4
Bulrush (*Scirpus* sp.)	10.5	
Water bulrush (*S. subterminalis*)	3.5	
Torrey's three-square bulrush (*S. torreyi*)	2.1	
Sedge (*Carex* sp.)	.6	
Large three-square bulrush (*Scirpus americanus*)	.4	
Soft-stemmed bulrush (*S. validus*)	.2	
River bulrush (*S. fluviatilis*)	.1	
Hard-stemmed bulrush (*S. acutus*)	Trace	
Bulrush (*S. smithii*)	Trace	
Bulrush (*S. paludosus*)	Trace	
Najadaceae		8.7
Eel grass (*Zostera marina*)	6.8	
Floating-leaved pondweed (*Potamogeton natans*)	1.1	
Pondweed (*P. pusillus*)	.4	
Widgeon grass (*Ruppia maritima*)	.2	
Pondweed (*Potamogeton* sp.)	.1	
Bushy pondweed (*Najas flexilis*)	.1	
Celery-leaved pondweed (*Potamogeton epihydrus*)	Trace	
Sparganiaceae		2.6
Bur reed (*Sparganium* sp.)	2.6	
Alismaceae		2.1
Arrow-head (*Sagittaria latifolia*)	2.1	
Arrow-head (*S. cuneata*)	Trace	
Isoetaceae		1.7
Quillwort (*Isoetes* sp.)	1.7	
Hydrocharitaceae		1.3
Wild celery (*Vallisneria spiralis*)	1.3	
Miscellaneous Vegetable Food		6.1
White pine (*Pinus strobus*)	1.0	
Large cranberry (*Vaccinium macrocarpon*)	.8	
*Yellow water lily (*Nuphar* sp.)	.2	
Wintergreen (*Gaultheria procumbens*)	.1	
Rose (*Rosa* sp.)	.1	
Water shield (*Brasenia schreberi*)	.1	
Miscellaneous vegetation	.1	
Smartweed (*Polygonum hydropiper*)	Trace	
Smartweed (*P. sagittatum*)	Trace	
Pigweed (*Chenopodium album*)	Trace	
Pickerel weed (*Pontederia cordata*)	Trace	
Coontail (*Ceratophyllum demersum*)	Trace	
Winterberry (*Ilex verticillata*)	Trace	
Unidentified plant material	3.7	
Total Vegetable Food		90.2
ANIMAL FOOD		
Gastropoda		7.1
Miscellaneous snails	6.9	
Snail (*Campeloma decisum*)	.2	

TABLE 2—(*Continued*)

	Percentage of total	Percentage of total
Insecta		*1.4*
Miscellaneous insects	*.9*	
Caddice-fly (Trichoptera)	*.2*	
Dragon-fly (Anisoptera)	*.2*	
Water-beetle (Haliplidae)	*.1*	
Miscellaneous Animal Food		*1.3*
Miscellaneous fish	*.6*	
Amphipod (*Gammarus* sp.)	*.4*	
Spotted salamander (*Triturus viridescens*)	*.3*	
Total Animal Food		*9.8*
Grand Total		*100.0*

or eight feet in depth. In spite of its widespread occurrence and importance in the northeast, previous literature made practically no mention of it as duck food. During the first year of the present study its value to many species of Maine ducks was apparent and this was recorded by Mendall and Gashwiler (1940).

Second group in importance among vegetable foods are the bur reeds. Several species occur in Maine but exact identification of their seeds beyond genus is difficult, when taken from duck stomachs, due to the grinding action in the gizzard. Those most frequently identified were of an emergent form, *Sparganium chlorocarpum*, and a floating species, *S. fluctuans*. Direct observations of feeding birds confirm the use of these species over the others. The giant bur reed, *S. eurycarpum*, is of restricted occurrence in Maine, but even when present is seldom fed upon. Only the seeds of bur reed were eaten in any quantities, although a few husks and fragments of leaves were ingested along with the seeds.

Closely following bur reeds in importance are the pondweeds of the three genera *Potamogeton*, *Najas*, and *Zannichellia*. Although seeds of ten different species were identified, those of the floating-leaved pondweed (*P. natans*) were of primary importance. This species is of widespread occurrence throughout Maine. In feeding upon pondweeds black ducks usually take only the seeds at this season of the year but a few rootstalks of *P. gramineus* and *P. pusillus* have been found in the stomachs presumably from plants found growing in shallow water.

Fourth most important group was the grass family (exclusive of domestic grains which are listed separately); of the various plants occurring, wild rice (*Zizania aquatica*) is by far the most important. This plant is found in various sections of the State but some of the heaviest stands occur in the inland tidal belt and the seeds are consumed in much greater quantity there (see Table 2). Even so, wild rice is of more importance in the interior than figures of Table 1 show. If a larger number of September stomachs had been available for analysis, wild rice would undoubtedly have had a higher rating. Numerous observations have indicated

that when the seeds are available in sufficient quantity wild rice is a preferred food. Even before the seeds ripen, blacks may be observed feeding on the flowers.

Tubers of the arrow-heads or duck potatoes are of local importance to black ducks along some of the rivers and streams but their over-all utilization is not great. Three species were identified with *Sagittaria latifolia* taken most often.

Domestic grains (barley, buckwheat, and oats) and smartweeds (seven species) each made up 2.6 per cent of the fall food of interior black ducks. Water pepper (*Polygonum hydropiper*) was the species of smartweed found most often. Smartweeds and grains are often highly important foods, locally, as will be discussed later.

The water lilies occur very commonly throughout Maine but furnish only a little of the fall food of black ducks. The same is true of pickerel weed (*Pontederia cordata*), although it is probable that the latter is locally important in September.

Animal food of black ducks as shown in Table 1 is chiefly divided among insects and snails with the larvae of dragon-flies being the only single item that is consumed in quantity.

INLAND TIDE WATER—92 STOMACHS

Fall foods of black ducks from tidal areas, where predominantly fresh water prevails, show striking differences from those of the interior, as Table 2 points out. The 92 specimens were taken largly from five collecting areas, in four of which considerable wild rice occurs. The importance of this plant (approximately 50 per cent of the total food) is clearly shown. No other member of the grass family is even represented.

Bulrushes as a group are of considerable importance but are utilized far less than in the interior. Eight species had been eaten with *Scirpus subterminalis* and *S. torreyi* again heading the list as in the interior.

Pondweeds (8.7 per cent) would be of only minor importance were it not for the eelgrass, *Zostera marina*. The presence of eelgrass seeds is not a true representation of feeding in the collecting area, however, and largely indicates coastal birds which had come into this area. Eelgrass occurs only sparingly in the waters making up the inland tide water classification.

Animal foods are of slight importance to black ducks in their fall feeding in this type of habitat. Snails, obtained chiefly at low tide, furnished most of such food.

COASTAL WATER—49 STOMACHS

Table 3 shows the results of analysis of the stomachs obtained in open coastal waters and in the strictly salt marshes. The collections represented feeding throughout the entire Maine coast from the mouth of the St. Croix River on the New Brunswick border to the Saco River marshes in southwestern Maine. The months of October and November are almost equally represented, with a few collections in late September.

Animal foods were heavily utilized by the coastal birds, with snails alone making up 50 per cent of the total stomach contents. Bivalves, chiefly mussels, were an important item in the birds' diet, constituting about 12 per cent of the food. Small amphipods, making up 8 per cent of the food, were fre-

TABLE 3.—FALL FOOD OF BLACK DUCKS FROM COASTAL WATER, 49 STOMACHS

	Percentage of total	Percentage of total
VEGETABLE FOOD		
Najadaceae		14.9
Eel grass (*Zostera marina*)	10.5	
Widgeon grass (*Ruppia maritima*)	4.3	
Pondweed (*Potamogeton pusillus*)	.1	
Gramineae		7.2
Wild rice (*Zizania aquatica*)	5.6	
Cord grass (*Spartina* sp.)	1.6	
Cyperaceae		1.7
Bulrush (*Scirpus* sp.)	1.5	
Bulrush (*S. paludosus*)	.1	
Spike rush (*Eleocharis palustris*)	.1	
Sedge (*Carex* sp.)	Trace	
Miscellaneous Vegetable Food		3.4
Sea lavender (*Limonium carolinianum*)	.1	
Sea blite (*Suaeda* sp.)	.1	
Raspberry or blackberry (*Rubus* sp.)	.1	
Smartweed (*Polygonum persicaria*)	.1	
Unidentified vegetable material	3.0	
Total Vegetable Food		27.2
ANIMAL FOOD		
Gastropoda		50.0
Miscellaneous snails	30.6	
Periwinkle (*Littorina palliata*)	6.7	
Periwinkle (*L. rudis*)	4.6	
Periwinkle (*L. litorea*)	4.5	
Snail (*Melampus bidentatus*)	2.0	
Snail (*Lacuna vincta*)	1.5	
Periwinkle (*Littorina* sp.)	.1	
Pelecypoda		11.9
Miscellaneous bivalves	5.4	
Horse mussel (*Modiolus modiolus*)	3.0	
Blue mussel (*Mytilus edulis*)	2.0	
Clam (*Macoma balthica*)	1.1	
Soft-shell clam (*Mya arenaria*)	.4	
Amphipoda		8.2
Amphipod (*Gammarus* sp.)	8.2	
Amphipod (*Asellus* sp.)	Trace	
Amphipod (*Idothea baltica*)	Trace	
Decapoda		2.2
Shrimp (*Crago septemspinosus*)	2.2	
Unidentified Animal Food		.5
Total Animal Food		72.8
Grand Total		100.0

quently consumed, especially in the salt marsh creeks.

Of the vegetable foods of coastal blacks, eelgrass was of most importance with widgeon grass (*Ruppia maritima*) also a favored food among the group of

pondweeds. The fact that over 10 per cent of all the coastal food consisted of eelgrass seeds is significant when it is considered that it was not until about 1944 that an appreciable recovery of this plant was noted following the effect of the blight of the 1930's.

Wild rice and cord grass (*Spartina* sp.) together made up slightly over seven per cent of the food. The wild rice, as well as a few other miscellaneous foods present in the stomachs, represented birds shot on the coast which had been feeding at inland areas.

It is of interest to compare the results of the present study with those compiled by McAtee, following segregation of McAtee's Maine data only. The earlier collections, 78 in number, were made from 1909 to 1911 inclusive and were confined to the coastal portion of southwestern Maine. The most striking difference is in the amounts of vegetable food consumed—about 67 per cent in McAtee's tabulation as against only 27 per cent in the present investigation. The shrinkage in the amount of coastal marshes through drainage, establishment of summer resorts, and industries, which has taken place in the past three or four decades has apparently forced black ducks to feed more over mud flats and around ledges; at such places the food would be largely animal material.

As would be expected, somewhat more use of eelgrass was made by McAtee's birds (12 per cent) than by those of the present study. Moreover, among 16 additional stomachs, collected in late summer and tabulated by McAtee, 11 per cent of the stomach contents consisted of eelgrass. A big difference was noted in the consumption of cord grass seeds—12 per cent as against less than two per cent shown in Table 3. Here again, a logical assumption lies in the present-day loss of much marsh habitat.

Small crustaceans and amphipods, common in small marsh creeks and pools, constituted about 14 per cent of the diet of the black ducks of these early collections of the Fish and Wildlife Service, while snails—so important in the present study—made up less than 6 per cent of the 1909–1911 food.

The two studies showed one common factor of considerable economic significance, in that no commercially important species of clam was found in any appreciable quantity.

WINTER FOOD

COASTAL WATER—34 STOMACHS

The stomachs making up the tabulations of winter food were all confined to coastal waters. As already explained, very little habitat is available to the birds at that time of year except the coastal bays and around the off shore islands. A few specimens were obtained in December from inland tide water but these were excluded from Table 4 as not being typical of winter food habits in the State as a whole. The 34 stomachs tabulated are well distributed throughout December, January, and February with a few in early March.

Vegetable foods were of slight importance in the diet of black ducks during cold weather and nearly 87 per cent of the food was of animal material. Snails furnished more than 60 per cent of the total. Bivalves were second in importance—mussels, together with a few non-edible clams, making up about 14 per cent of the food analyzed. Various

TABLE 4.—WINTER FOOD OF BLACK DUCKS FROM COASTAL WATERS, 34 STOMACHS

	Percentage of total	Percentage of total
VEGETABLE FOOD		
Rhodophyceae		3.0
Marine algae	3.0	
Plumbaginaceae		2.6
Sea lavender (*Limonium carolinianum*)	2.6	
Gramineae		2.3
Cord grass (*Spartina* sp.)	2.3	
Miscellaneous Vegetable Food		5.2
Pigweed (*Chenopodium* sp.)	.4	
Sea blite (*Suaeda* sp.)	.3	
Unidentified plant material	4.5	
Total Vegetable Food		13.1
ANIMAL FOOD		
Gastropoda		60.9
Miscellaneous snails	23.4	
Periwinkle (*Littorina palliata*)	10.3	
Periwinkle (*L. litorea*)	9.0	
Periwinkle (*Littorina* sp.)	7.2	
Snail (*Thais lapillus*)	5.7	
Mud snail (*Nassa obsoleta*)	2.9	
Snail (*Littorina rudis*)	2.2	
Limpet (*Acmaea testudinalis*)	.1	
Snail (*Lacuna vincta*)	.1	
Pelecypoda		13.7
Blue mussel (*Mytilus edulis*)	8.9	
Miscellaneous clams or mussels	4.6	
Horse mussel (*Modiolus modiolus*)	.2	
Amphipoda		11.5
Amphipod (*Gammarus* sp.)	5.5	
Amphipod (*Orchestia platensis*)	4.1	
Miscellaneous amphipods	1.9	
Miscellaneous Animal Food		.8
Spiny-rayed fish	.5	
Miscellaneous insects	.3	
Total Animal Food		86.9
Grand Total		100.0

species of amphipods constituted the only other important food group. These findings are similar to those of Addy (1945) who reports that along the Massachusetts coast most of the black duck food after December 1 is of animal material.

The records of 23 stomachs from the Fish and Wildlife Service files were available for comparison. These were all obtained in December from 1909 to 1911 and collections were restricted to southwestern Maine. The only significant differences in the two investigations lie in the use of cord grass and eelgrass. The former made up nine per cent of the food in the earlier study. Eelgrass was utilized to the extent of

TABLE 5.—SPRING FOOD OF BLACK DUCKS FROM INLAND FRESH WATER, 31 STOMACHS

VEGETABLE FOOD

	Percentage of total	Percentage of total
Cyperaceae		37.8
Sedge (*Carex* sp.)	18.2	
Sedge (*C. crinita*)	5.2	
Spike rush (*Eleocharis palustris*)	4.1	
Twig rush (*Cladium mariscoides*)	4.1	
Spike rush (*Eleocharis* sp.)	2.5	
Lake sedge (*Carex lacustris*)	1.5	
Sedge (*C. intumescens*)*	.9	
Soft-stemmed bulrush (*Scirpus validus*)	.9	
*Sedge (*Carex tuckermani*)	.3	
Three-way sedge (*Dulichium arundinaceum*)	.1	
Hard-stemmed bulrush (*Scirpus acutus*)	Trace	
Spike rush (*Eleocharis obtusa*)	Trace	
Sparganiaceae		27.6
Bur reed (*Sparganium* sp., chiefly *S. chlorocarpum*)	27.6	
Polygonaceae		6.9
Water pepper (*Polygonum hydropiper*)	2.6	
*Water smartweed (*P. natans*)	2.3	
Long-seeded smartweed (*P. pennsylvanicum*)	1.4	
Smartweed (*Polygonum* sp.)	.6	
Najadaceae		2.9
Celery-leaved pondweed (*Potamogeton epihydrus*)	1.3	
Pondweed (*Potamogeton* sp.)	.7	
Floating-leaved pondweed (*P. natans*)	.6	
Pondweed (*P. pusillus*)	.3	
Domestic Grains		2.8
Oats (*Avena* sp.)	2.8	
Cornaceae		2.3
Round-leaved dogwood (*Cornus rugosa*)**	2.2	
Dogwood (*Cornus* sp.)	.1	
Haloragidaceae		1.8
Mermaid-weed (*Proserpinaca palustris*)	1.8	
Water milfoil (*Myriophyllum* sp.)	Trace	
Rosaceae		1.7
Cherry (*Prunus* sp.)	1.0	
Rose (*Rosa* sp.)	.6	
Raspberry or blackberry (*Rubus* sp.)	.1	
Juncaginaceae		1.5
Arrow grass (*Scheuchzeria palustris*)*	1.5	
Gentianaceae		1.1
Buckbean (*Menyanthes trifoliata*)	1.1	
Miscellaneous Plant Food		6.2
Black mustard (*Brassica nigra*)	.9	
Large cranberry (*Vaccinium macrocarpon*)	.5	
Water buttercup (*Ranunculus* sp.)	.4	
Staghorn sumac (*Rhus typhina*)	.3	
Miscellaneous plant food	.1	
Wild rice (*Zizania aquatica*)	Trace	
Unidentified plant material	4.0	
Total Plant Food		92.6

TABLE 5—(*Continued*)

	Percentage of total	Percentage of total
ANIMAL FOOD		
Insecta		3.7
Dragon-fly (Anisoptera)	2.4	
Dragon-fly or damsel-fly (Odonata)	.7	
Miscellaneous beetles (Coleoptera)	.3	
Caddice-fly (Trichoptera)	.2	
Miscellaneous bugs (Hemiptera)	Trace	
Alder-fly or sialid (Neuroptera)	Trace	
Miscellaneous insects	.1	
Gastropoda		3.6
Miscellaneous snails	3.6	
Miscellaneous Animal Food		.1
Miscellaneous mollusks	.1	
Total Animal Food		7.4
Grand Total		100.0

* From Gray's Manual—not listed by Hotchkiss or Fassett.
** From Hyland and Steinmetz (1944)—formerly called *C. circinata.*

five per cent, while it did not show up at all as a winter food in the present study.

Some interesting observations concerning eelgrass appear worthy of inclusion. Field checks conducted by the writer in January of both 1945 and 1946 indicated heavy feeding by black ducks at low tide on eelgrass beds in two bays of Knox County. Eelgrass had been practically non-existent in these two areas from 1935 to 1942 and wintering black ducks had been very scarce during that time. In 1943 a few small patches of eelgrass were found and these spread in 1944, 1945, and 1946. Apparently as the eelgrass became reestablished, the black ducks began once more to use these areas which for eight years they had practically forsaken.

SPRING FOOD

INLAND FRESH WATER—31 STOMACHS

It was deemed unwise to make extensive collections of ducks just prior to or during the nesting season, even in view of the benefits to be gained by a year-round food study. Fortunately for the investigation, but unfortunately for the duck population, many birds are caught each spring during the muskrat trapping season. The season varies somewhat from year to year but during most of the time covered by the present study was from April 1 to May 10. Half a dozen specimens were collected in late May and June (adult males that were not attending females) but all others were obtained through muskrat trapping. About 50 specimens were available for the spring season but only 31 contained enough food in the digestive tracts to permit tabulation.

As was the case with fall specimens from interior waters the family Cyperaceae was the most important in furnishing black duck foods. But rather than the bulrushes of fall, the sedges are of greatest use in spring. Seeds of four distinct species of *Carex* were found in the stomachs and there were others present which could not be positively identified beyond the genus. Altogether,

sedge seeds made up 26 per cent of the spring food. Spike rushes (chiefly seeds but occasionally roots or tubers) made up nearly seven per cent of the diet at this season.

Bur reeds of various species, but with seeds of *Sparganium chlorocarpum* predominating, provided slightly over 27 per cent of the black duck diet in spring.

Direct observations of feeding birds further bear out the importance of sedges and of the emergent bur reed (*S. chlorocarpum*). During early spring, water levels are normally very high and it is in flooded sedge meadows and swales where, from necessity, most of the black duck feeding is carried out. Many feed beds which are utilized extensively in summer and fall are too far under water for surface feeding ducks in April and May.

Smartweeds of several species made up about seven per cent of the food. Observations by the writer have indicated heavy local use of smartweeds, especially the marsh and semi-terrestrial varieties, when these plants occur in areas where the birds tend to concentrate during migration.

Seeds of pondweeds and those of domestic grains headed a long list of miscellaneous vegetable foods of minor importance. Many of these foods such as dogwoods, rose, cherry, etc. were obviously available because of spring flood waters. Domestic grains have been found by observation to be of considerably more importance locally than the stomach examinations indicated; this point is discussed more fully in a later section of this paper.

The total vegetable food reaches its greatest utilization during spring—more than 92 per cent. Animal food is comparatively unimportant at this season of the year.

Summer Food

ADULTS—INLAND FRESH WATER—22 STOMACHS

Because of the undesirability of breaking up nesting pairs or females with broods, only a limited number of specimens was collected during the summer months. About half of the 22 stomachs used in this study (Table 6) were obtained during the first three weeks of September; the remainder represent about equally the months of July and August. Data thus obtained are not extensive but are supplemented by a large number of direct observations of feeding.

Bulrushes reach their highest utilization by black ducks during the summer months—especially in August and September—and the family Cyperaceae thus furnished over half of all the food eaten by the ducks examined. Water bulrush and Torrey's three-square bulrush made up practically all of this total. As was the case in the fall tabulations, it is the tubers and rootstalks of the bulrushes that are of chief importance.

Bur reed demonstrated its importance as a year-round food of note, with 7.7 per cent, slightly exceeding wild rice. Pondweeds and pickerel weed (*Pontederia cordata*) ranked next in importance to wild rice. Observations by Jay S. Gashwiler and the writer indicate that pickerel weed and also buckbean (*Menyanthes trifoliata*) are often important in a few areas. Buckbean fruits very early, and if more collections had been made in August it is likely that the plant would have appeared much more frequently than it did. In Massachusetts, Addy (1945) found pickerel weed to be a fairly important September food of black ducks.

TABLE 6.—SUMMER FOOD OF ADULT BLACK DUCKS, 22 STOMACHS

VEGETABLE FOOD	Percentage of total	Percentage of total
Cyperaceae		53.2
Water bulrush (*Scirpus subterminalis*)	36.3	
Torrey's three-square bulrush (*S. torreyi*)	15.5	
Three-way sedge (*Dulichium arundinaceum*)	.6	
Spike rush (*Eleocharis palustris*)	.5	
Twig rush (*Cladium mariscoides*)	.2	
Sedge (*Carex* sp.)	.1	
Hard-stemmed bulrush (*Scirpus acutus*)	Trace	
Spike rush (*Eleocharis* sp.)	Trace	
Triangle spike rush (*E. robbinsii*)	Trace	
Sparganiaceae		7.7
Bur reed (*Sparganium* sp.)	7.7	
Gramineae		7.0
Wild rice (*Zizania aquatica*)	7.0	
Najadaceae		4.3
Floating-leaved pondweed (*Potamogeton natans*)	2.6	
Variable pondweed (*P. gramineus*)	.9	
Celery-leaved pondweed (*P. epihydrus*)	.6	
Pondweed (*P. obtusifolius*)	.1	
Pondweed (*P. spirillus*)	.1	
Pondweed (*P. pusillus*)	Trace	
Pontederiaceae		3.9
Pickerel weed (*Pontederia cordata*)	3.9	
Nymphaecae		3.6
Water shield (*Brasenia schreberi*)	3.5	
*Yellow water lily (*Nuphar* sp.)	.1	
Gentianaceae		1.4
Buckbean (*Menyanthes trifoliata*)	1.4	
Unidentified Vegetable Food		.9
Total Vegetable Food		82.0
ANIMAL FOOD		
Gastropoda		11.6
Miscellaneous snails	6.7	
Snail (*Campeloma decisum*)	4.4	
Snail (*Amnicola limosa*)	.4	
Miscellaneous snails	.1	
Snail (*Physa heterostropha*)	Trace	
Snail (*Helisoma* sp.)	Trace	
Insecta		6.1
Dragon-fly (Anisoptera)	2.8	
Alder-fly (Sialinae)	.6	
Dragon-fly or damsel-fly (Odonata)	.5	
Giant water-bug (Belostomatidae)	.4	
Miscellaneous beetles (Coleoptera)	.2	
Back-swimmer (Notonectidae)	.1	
Whirligig-beetle (*Gyrinus* sp.)	.1	
Miscellaneous insects	1.4	
Unidentified Animal Material		.3
Total Animal Food		18.0
Grand Total		100.0

TABLE 7.—FOOD OF DOWNY YOUNG BLACK DUCKS, 11 STOMACHS

VEGETABLE FOOD

		Percentage of total	Percentage of total
Najadaceae			11.3
Floating-leaved pondweed (*Potamogeton natans*)		7.0	
Pondweed (*P. pusillus*)		2.0	
Pondweed (*Potamogeton* sp.)		1.5	
Bushy pondweed (*Najas flexilis*)		.6	
Celery-leaved pondweed (*Potamogeton epihydrus*)		.2	
Gramineae			8.8
Wild rice (*Zizania aquatica*)		8.8	
Cyperaceae			5.8
Spike rush (*Eleocharis palustris*)		2.0	
Sedge (*Carex* sp.)		1.8	
Three-way sedge (*Dulichium arundinaceum*)		1.4	
Water bulrush (*Scirpus subterminalis*)		.5	
Torrey's three-square bulrush (*S. torreyi*)		.1	
Twig rush (*Cladium mariscoides*)		Trace	
Sparganiaceae			2.3
Bur reed (*Sparganium* sp.)		2.3	
Unidentified Plant Material			4.1
Total Plant Food			32.3

ANIMAL FOOD

Insecta			33.0
Coleoptera		11.6	
Miscellaneous beetles	5.0		
Leaf-beetle (Chrysomelidae)	3.4		
Engraver-beetle (Scolytidae)	2.5		
Click-beetle (Elateridae)	.4		
Diving-beetle (Dytiscidae)	.2		
Snout-beetle (Curculionidae)	.1		
Odonata		4.8	
Dragon-fly (Anisoptera)	4.7		
Damsel-fly (Zygoptera)	.1		
Trichoptera		3.4	
Caddice-fly	3.4		
Diptera		2.4	
Horse-fly (Tabanidae)	.5		
Midge (Chironomidae)	.1		
Miscellaneous flies	1.8		
Hemiptera		1.8	
Water-strider (*Gerris* sp.)	1.7		
Back-swimmer (*Plea striola*)	.1		
Lepidoptera		.8	
Moths and butterflies	.8		
Neuroptera		.2	
Sialid (Sialidae)	.2		
Ephemerida		.1	
May-fly	.1		
Miscellaneous Insects		7.9	
Gastropoda			18.7
Miscellaneous snails	9.0		
Snail (*Campeloma decisum*)	6.8		
Snail (*Lymnaea* sp.)	2.9		

TABLE 7—(*Continued*)

	Percentage of total	Percentage of total
Pelecypoda		*15.0*
Miscellaneous bivalves	*12.7*	
Pill clam (*Pisidium* sp.)	*2.3*	
Miscellaneous Animal Food		*1.0*
Fresh-water shrimp (*Hyalella* sp.)	*.9*	
Spider (Arachnida)	*.1*	
Total Animal Food		*67.7*
Grand Total		*100.0*

Animal material constituted less than one fifth of the total summer food of adult ducks and was largely made up of snails and insects.

DOWNY YOUNG—INLAND FRESH WATER 11 STOMACHS

In view of the limited knowledge of the specific food habits of young ducks, the eleven stomachs available for examination were very enlightening. Numerous observations of the feeding activities of the broods had indicated the importance of animal life but exactly what insects and other organisms were consumed was unknown.

Animal foods predominated heavily in the stomach contents and made up slightly over two thirds of the entire diet. Insects, principally the larvae, were foremost. Although many species were identified, those of outstanding importance were dragon flies, caddice flies, and various aquatic beetles. Plants such as the water lilies and pickerel weed—relatively unimportant as black duck foods—play a very important role in harboring insects and hence are favorite feeding sites during the brood season.

Following insects, snails and fresh water clams and mussels are next in importance to the young ducks.

Both stomach examinations and observations indicate that after the ducklings are a week or 10 days old they commence feeding more and more on vegetable material until by the time they are half grown their food habits are similar to those of adults. For that reason all specimens used in preparing Table 7 were of ducklings less than three weeks old. Principal vegetable foods of these birds were found to be pondweeds, wild rice, and plants in the sedge family. Several species of pondweeds were utilized but the floating-leaved pondweed (*Potamogeton natans*) was of foremost importance. Wild rice was found only in the stomachs of birds collected in August but, when available, it is a favorite food of young birds as it is with adults. At times the ducks start feeding on the flowers even before the fruit appears.

MISCELLANEOUS SIGHT RECORDS

The foregoing tables show, within certain definite limits, what constituted the average black duck diet during the present study, as far as stomach examinations were concerned. But con-

siderable data, derived from observation, indicated that a number of other foods are at times of considerable importance to the birds. Some of these records, when definite assurance was obtained as to exactly what the birds were feeding on, are presented at this time.

Several species of pondweeds, not recorded in Tables 1 to 7, are known to be eaten by Maine black ducks. One of these is the large-leaved pondweed, *Potamogeton amplifolius*. This plant has a very erratic distribution in Maine but in some waters it grows abundantly and at such times is taken as readily as the more common *P. natans*. In late September, 1944, black ducks were watched for a considerable period of time feeding on both the seeds and roots of *P. amplifolius* in a pond in northern Maine where the plant was growing in six inches of water. Again in October, 1946 at the same area, several birds were seen feeding on this pondweed and the water was littered with its root fragments and also those of the bur reed, *Sparganium angustifolium*. On September 30 and October 1, 1946—at Williamstown Lake, New Brunswick (within a few miles of the Maine border)—black ducks were found feeding extensively on both the seeds and roots of *Potamogeton amplifolius*. Although the plant was growing in 4 feet of water, the root particles had been dislodged by diving ring-necked ducks and were therefore available to the blacks as well.

Pipewort (*Eriocaulon* sp.) does not ordinarily afford duck food. But on May 8, 1942 a mixed flock of about a dozen blacks and 15 ring-necked ducks were feeding heavily on the roots of this plant in a cove of a lake in eastern Maine. The ring-necks were digging up the plants after which the blacks fed upon the drift.

Muskgrass (*Chara* sp.) is seldom utilized as food by any species of duck in Maine, and it did not show up during the present study except through direct observation. On October 5, 1946 it was furnishing a limited amount of food for a large flock of black ducks and pintails at a shallow lake in the northern part of the State.

In August, 1947 a nearly grown black duck was watched feeding at close range (ten feet) for 15 minutes. It stood in the middle of a small, fast-running brook feeding on the leaves of waterweed (*Elodea* sp.).

INDIVIDUAL STOMACH RECORDS

Although having little bearing on an over-all picture of black duck foods in Maine, an examination of some of the individual stomach records comprising Tables 1 to 7 show many interesting and unusual instances of individual feeding.

Except when feeding, undisturbed, in lush beds of a few choice plants such as wild rice, eelgrass, or in grain fields, a black duck "meal" usually consists of several different kinds of foods and five to ten items ordinarily will comprise the stomach contents. The stomach of one bird shot in central Maine in October however, contained 25 separate items including 17 tubers of wild celery and over 2000 seeds of bushy pondweed.

A bird shot in October on the Penobscot River had eaten over 4000 seeds of white birch besides 29 c.c. of other food.

Three-way sedge (*Dulichium arundinaceum*) is sparingly utilized by black

ducks as a group but one individual taken in October had eaten 700 seeds of this species. Apparently the bird had fed on the plant from choice as it was flushed in an area having a considerable variety of aquatic vegetation.

Several instances were noted of more than casual feeding on terrestrial foods apart from grain. The stomach of one bird contained about 800 seeds of *Rubus* sp. (raspberry or blackberry). A bird taken in October from a marsh which contained both wild rice and pondweeds had fed on hardwood fruits entirely—27 seeds of dogwood were present in the stomach; also 472 seeds and 13 whole fruits of winterberry (*Ilex verticillata*). In this connection John M. Dudley has related to the writer that a few years before the collections for this study were made in the Pocamoonshine-Crawford area, he observed considerable utilization of winterberry by black ducks. At that time unusually high water prevailed and a number of birds were flushed from flooded islands containing large clumps of fruiting winterberry. Several of the blacks were shot and all had these fruits in their digestive tracts.

The stomach of a bird taken in October on the Kennebec River contained over 300 seeds of white pine. One bird taken in fall near coastal waters had fed upon such typically oceanic food as eelgrass but, in addition, had eaten rose "hips," wintergreen fruit, and blueberries.

The quantity of food which is consumed by black ducks is sometimes surprising. Ordinarily, stomachs examined in this study contained less than 25 c.c. of food regardless of when or how they were collected. But occasionally evidence of heavy "stuffing" was obtained, especially when feeding upon favorite items. The stomach of a bird obtained in April contained over 1500 smartweeds seeds and nearly 1500 seeds of oats. The total contents, exclusive of grit, was 74 c.c.

A bird, taken on the coast in November had over 3600 seeds of eelgrass and more than 600 small snails, clams, and mussels in its gizzard and oesophagus.

In spite of the bulkiness of wild rice, a specimen from Merrymeeting Bay contained 1350 seeds of this plant. Wild rice has made up all of the food present in the digestive tract.

A bird shot in a grain field had gorged itself so much as to take wing only with difficulty. 2400 seeds of buckwheat were present and the total food content was 78 c.c.

The record quantity of food observed in a black duck stomach during this study was 80 c.c. plus an additional 3 c.c. of grit. Arrowhead tubers, of which 456 had been consumed, made up 98 per cent of the food in this instance.

FACTORS AFFECTING FOOD CHOICE

In the preceding pages, the average diet of black ducks by seasons and habitat types has been presented. There are several factors which affect the utilization of the wide variety of foods listed in Tables 1 to 7. Among the more important of these are availability—as determined by water levels and to a lesser extent by climatic conditions, abundance, hunting pressure, food preferences, and human intrusion apart from hunting.

WATER LEVELS

No matter what the abundance of a

particular food item may be or how much this may be preferred by the duck, water levels may frequently render such food unavailable. In seasons when unusually low water prevails many submerged aquatic plants and animal organisms such as snails and clams become potential sources of food which otherwise would be out of reach of surface feeding ducks. On the other hand many semi-aquatic or terrestrial plants are utilized heavily only when the water is so high as to permit the ducks to swim into areas which might normally be dry land. The wide variety of what may be termed second rate food that is eaten in spring is a direct result of the high water levels of that season of the year. In any management program that involves food planting, careful consideration should be given to the seasonal water levels that are likely to prevail in the particular marsh to be managed.

Some specific data on the various factors affecting food choice were obtained from the Pocamoonshine-Crawford study area in eastern Maine. Here, with the assistance of John M. Dudley, over 100 primarily fall birds were obtained over a period of five consecutive years; 94 fall stomachs contained sufficient food for tabulation. On this area, water level data were recorded, a sample floristic survey was made, and a rough vegetative map prepared. No important habitat changes occurred during the period but there were very definite seasonal and annual differences in water levels. Corresponding changes in the feeding areas and plant associations frequented by the birds were observed. Such data as were obtained by an analysis of the fall-collected stomachs are shown in Table 8 which, for simplification, lists only the leading foods.

TABLE 8.—LEADING FALL FOODS OF BLACK DUCKS
Pocamoonshine-Crawford Area—94 Stomachs

Year	No. Stomachs	Water Levels	Percentages of Leading Foods							
			Water Bulrush	Torrey's Three-square Bulrush	Bur Reeds	Water Lillies (chiefly Water Shield)	Pond-weeds	Spike Rushes	Pickerel Weed	Animal Food
1941	19	Very low	62.8	1.2	8.9	1.3	1.9	Trace	1.0	17.4
1942	22	Slightly high	34.1	42.4	12.0	1.1	.5	Trace	Trace	8.6
1943	7	Very high	14.3	37.3	5.9	—	Trace	11.0	10.0	.6
1944	15	Slightly low	72.8	6.6	7.6	3.6	2.0	1.6	Trace	2.4
1945	31	About average	30.5	53.9	4.3	1.9	2.6	.2	.2	2.7
5 Year Total	94		43.4	31.8	7.7	1.7	1.7	1.1	1.0	6.3

On the study area the chief food, water bulrush, grows in a few inches of water in the numerous shallow potholes and back channels of the marsh; and in deep water of the main stream which winds throughout the entire area between Pocamoonshine and Crawford lakes. In an autumn when water levels are average or only slightly below average, black ducks can obtain the tubers of water bulrush in abundance in the potholes and to some extent in the shallower portions of the main channel.

Under extremely low water conditions, many beds of the plant which ordinarily would be covered by two to four feet of water in the channel become available. As the water rises above average fall levels, water bulrush is used less frequently because even in the potholes most of the tubers are too far under water for the birds to obtain.

In the case of Torrey's three-square bulrush it was found that nearly the opposite situation prevails. In the Pocamoonshine area, this plant usually occupies the outer edge of the sedge meadows—filling the gap between almost solid sedge and the pickerel weed at the edge of the channel. Normally in fall it will be found in two to five inches of water thus permitting the birds to alight in it or swim through it, and to feed on the tubers with considerable protective cover around them. In low water the beds of three-square are on dry land and go almost untouched by the black ducks. In extremely high water some use is made of the plant—deep in the marsh where it is interspersed with the sedges—but it is utilized most extensively when average to slightly above average water levels prevail.

Bur reeds are fairly important sources of food in the Pocamoonshine area regardless of water levels but the species varies with the height of water. With low waters the floating or submerged bur reeds (*S. fluctuans* and a little *S. minimum*) are eaten extensively, but during high water the emergent species (*S. chlorocarpum*) is the one that is fed upon principally.

Spike rush seeds made up only a little over one per cent of the total food of this group of birds during the five year period, but with the very high water of 1943 it was utilized to the extent of 11 per cent. In that year the birds could swim among the stems, feeding on the seeds almost at water level. The same situation occurred in the case of pickerel weed, a plant seldom used as food during the other four years.

The pondweeds, used only slightly in any year, furnished practically no food at all when water levels higher than average occurred.

Animal foods showed their greatest usage in 1941 when extremely low waters prevailed and when considerable stretches of open mud flats were present along the channels; their lowest consumption was during the high water year of 1943. The relatively high usage in 1942, however, does not suggest any explanation.

The effects of water levels on foods were apparent many times, apart from the special study made in the Pocamoonshine area. Pondweeds, water bulrush, snails and insects have always reached their greatest utilization in years of low water. On the other hand, wild rice, rice cut-grass, arrowhead tubers, smartweeds, and sedges are fed upon much more extensively in years of relatively high water.

ABUNDANCE

Many foods are important in particular waterways largely because they are abundant and easily obtained and not necessarily because the black ducks exhibit a particular fondness for them. This is particularly true of animal foods in tidal waters, and of such vegetable foods as cord grass. Even preferred foods, such as eelgrass and wild rice, may be passed up in favor of more

abundant foods if they occur in limited and scattered amounts. Of course, abundance is to a considerable extent tied in with the other factors being discussed and its own effect on black duck dietary habits is sometimes difficult to interpret. Nevertheless, a correlation between abundance of a food item and its utilization by the birds will explain many of the differences in food habits in various areas. It is an important consideration in management of marshes and clearly illustrates the need for local surveys before planting programs are carried out.

It was beyond the scope of the present study to conduct detailed inventories of the animal and plant resources of Maine's marshes, but rough estimates were made of the relative abundance of the aquatic plants on a majority of the important marshes of the State.

The Pocamoonshine-Crawford study area covers a tract of marsh and water totaling nearly 10 square miles. In Table 9, 20 plant species or genera are shown in the relative order of abundance; also the degree of utilization of each, as based on stomach analysis of 94 fall-collected specimens. For simplicity, the descriptive terms are restricted to as few as possible. In general, foods were listed as *abundant* or *common*

TABLE 9.—ABUNDANCE AND UTILIZATION OF FOOD PLANTS IN FALL
Pocamoonshine-Crawford Area

Plant	Abundance	Utilization	Plant Significance Rating*
Water bulrush	Abundant	Heavy	20
Water lilies	Abundant	Slight	10
Sedges	Abundant	Very slight	5
Military rush	Abundant	None	0
Manna grass	Abundant	None	0
Three-way sedge	Abundant	Very slight	5
Pickerel weed	Abundant	Slight	10
Torrey's three-square bulrush	Common	Heavy	16
Pondweeds	Common	Slight	8
Bur reeds	Common	Moderate	12
Muskgrass	Common	None	0
Water milfoil	Common	None	0
Coontail	Common	None	0
Wool grass	Common	None	0
Spike rushes	Scattered	Slight	6
Arrowhead	Scattered	Very slight	3
Round-stemmed bulrushes	Scattered	Very slight	3
Smartweeds	Scarce	None	0
Wild rice	Scarce	None	0
Wild celery	Very scarce	Very slight	1

* This column represents merely an arbitrary numerical rating, designed to give the reader a better idea of the significance in this one marsh of the various plants, based on both their abundance and utilization. Numerical values were assigned for abundance as follows: abundant—5, common—4, scattered—3, scarce—2, very scarce—1. Utilization ratings were given thus: heavy—4, moderate—3, slight—2, very slight—1, none—0. The significance rating for any given plant is obtained by multiplying the numerical assignment of its abundance by that of its utilization.

only if they were available throughout the entire area and were plants on which the birds could stuff themselves if they desired to do so. As may be noted by comparing some of the plants in this listing with Table 8, *heavy* utilization is assigned to those foods which had been eaten to the extent of more than 10 per cent. A plant furnishing from five to 10 per cent of the total food was given a utilization rating of *moderate:* from one to five per cent was termed *slight;* and from 0.1 to one per cent was considered as *very slight.*

It should be kept in mind that water levels influence the food selections, as discussed in the preceding section, but the listing in Table 9 reveals several significant points. Spike rush was the only item lacking an *abundant* or *common* rating which furnished more than one per cent of the total food of the 94 black ducks. Two choice foods over the State as a whole, wild rice and smartweed, even though not common on the area were present nonetheless, but they received practically no utilization by the birds, appearing as traces. Many plants rated as abundant or common were not utilized; in some of these, such as the submerged forms, availability through water levels is a factor; while others such as military rush (*Juncus militaris*) and wool grass are plants that are rarely if ever acceptable as black duck foods in Maine, regardless of their abundance.

In striking contrast to the food habits of the Pocamoonshine birds, it may be of interest to consider another particular group of black ducks—those from Togus Pond, Togus Stream, and several nearby sloughs near Augusta in south-central Maine. On these combined marshes, wild rice and various pondweeds (chiefly *Potamogeton natans*) are the most abundant of the potential duck food plants. Water bulrush, various water lilies, and bur reeds are also quite common. Smartweeds, pickerel weed, and manna grass are scattered but not particularly common. Twenty-six stomachs were obtained from this area in fall. Wild rice made up nearly 26 per cent of the total food with pondweeds close behind at approximately 25 per cent. Water bulrush followed with 17 per cent, and bur reed was fourth in importance at six per cent. All other plant foods received only slight use. The figures have added significance when compared with those of Table 1 giving the over-all fall diet of inland birds. Both wild rice and pondweeds were eaten far in excess of the "average" Maine black duck. Water bulrush was consumed slightly less than the average while bur reeds were eaten considerably less.

At Merrymeeting Bay (inland tidal classification) an extremely restricted diet is indicated in spite of a great variety of aquatic plants. In 1938 Jay S. Gashwiler made a rough determination of the relative abundance of the important plants in the bay. He estimated that over 20 per cent of all the vegetation available to ducks in late summer and fall consisted of wild rice; 12 per cent of the potential food consisted of the large three-square bulrush (*Scirpus americanus*); all other emergent bulrushes constituted about 12 per cent; yellow water lily was slightly less than 10 per cent; sweet flag seven per cent; and pickerel weed six per cent. The remaining amount of vegetation was distributed among many species.

Water bulrush, bur reeds, and pondweeds were all present but in amounts totaling less than five per cent. Collections in the fall from Merrymeeting Bay amounted to 64 stomachs. Of these wild rice alone made up about 59 per cent of the total food. The various emergent bulrushes had been eaten to the extent of slightly over 15 per cent. No other single food item had been consumed appreciably although water bulrush and bur reeds each composed about three per cent of the diet.

Grain (oats, buckwheat, and barley) made up only 2.6 per cent of the fall food of interior black ducks as a group (see Table 1), but in extreme northern Maine where many large grain fields are adjacent to waterfowl habitats, a much different picture is obtained. Twenty-nine fall birds from the upper St. John Valley had fed upon grain to the extent of nearly 24 per cent of their total food.

A plant which hitherto had not been considered as a duck food is the triangle spike rush (*Eleocharis robbinsii*). It occurs sparingly throughout Maine as a whole, having a very erratic distribution. Occasionally it grows abundantly in a few areas as in the Davis-Holbrook marsh of central Maine. There its abundance greatly exceeds that of any of the other important waterfowl food plants including water bulrush, Torrey's three-square bulrush, or the bur reeds. Numerous observations as well as the examinations of a few stomachs have shown this to be an important food locally as pointed out by Coulter (1948). This plant made up 51 per cent of the food of 3 blacks collected there in October, 1946.

EFFECTS OF HUNTING

Barring poaching and various types of disturbances by man, it may be assumed that black ducks can feed about where they wish to during the greater part of the year, influenced only by natural factors. In the fall, however, the feeding routine is subject to a departure from the normal because of the hunting season. Stoudt (1944) has clearly pointed out, in the case of mallards in Minnesota, that favorite feeding grounds can be quickly "burned out" by heavy concentrations of hunters and that food studies based upon stomach analysis when hunting pressure is great are misleading in that second rate food is obtained by the ducks from necessity. Stoudt shows very convincingly that wild rice, for example, is a much more important source of food to Minnesota mallards than stomach records from that state show.

In Maine, there is no doubt but that radical changes in the dietary habits of black ducks often occur abruptly at the start of the hunting season. This disturbance is principally restricted to the first two or three days of the season, and to Saturdays and holidays; also to the last few days of the season at a few coastal areas. There is a strong probability that vegetable foods would have ranked higher in Table 3 had there been less hunting in the coastal marshes; this forced the birds to feed more extensively around offshore islands and on open mud flats where they are not so susceptible to the gun. The writer has seen several instances of birds shifting their feeding grounds from small potholes and sloughs to rivers and large ponds—with quite different food intake resulting—because of sustained hunting pressure. Black ducks feeding regularly on grain can become so "gun shy" in

an hour or two of heavy shooting as to forsake the grain fields for several days.

But on the whole, hunting pressure in Maine is so slight in comparison with many states that it does not appear to materially influence the food habits of black ducks in any save coastal waters. Hunting pressure in the interior of the State appears to have two effects on the birds, both influencing feeding routines rather than foods. It may change their feeding locations from the settled to the remote waterways. But Maine has such a wide dispersion of lakes, ponds, streams, and rivers, that even if the birds are driven from one area another similar one is usually located nearby. Hunting pressure also changes the feeding times. With the open season, black ducks feed more and more at twilight and dawn and during the night. Even in Merrymeeting Bay, where the greatest concentration of hunters occurs and where shooting is not merely confined to a few days but continues as long as the bay remains open, the birds continue to do a great deal of feeding there. The fact that nearly 60 per cent of the food of the 64 Merrymeeting Bay birds consisted of wild rice indicates that not a great deal of shift from marsh to open water feeding had occurred, despite gun pressure.

Although the effects of the gun on the fall diet of black ducks cannot be overlooked, it is believed that the general food habits of the birds in Maine are not materially changed by the rather limited hunting pressure that exists at the present time, except in a few of the coastal marshes.

FOOD PREFERENCES

An interpretation of the degree to which a given food may actually be preferred by black ducks is very difficult with the effects of the preceding factors complicating any evaluation. Nevertheless, the utilization of certain plants out of proportion to their abundance and availability can only be interpreted as evidence of deliberate selection, or avoidance, by black ducks.

Reference to Tables 8 and 9 will shed some light on these points. Hunting pressure is very slight in the Pocamoonshine-Crawford area. The 94 birds collected there for this study over a 5-year period are believed to greatly exceed the number killed by all other hunting combined. Moreover, most of the birds shot there were not killed while coming into the marshes but were flushed from feeding areas. Therefore the hunting factor can be largely eliminated as affecting food selection. It is quite evident from Table 9 that military rush, manna grass, three-way sedge, the true sedges, muskgrass, water milfoil, coontail, and wool grass were largely avoided by the birds, despite the fact that each was abundant or common and that there were enough differences in water levels during the 5-year period to permit considerable feeding on each of these items had the birds desired to do so. By checking the percentages of Table 1 it can be seen that the data obtained on these plants in the Pocamoonshine area are quite typical for the State as a whole. All of them are common plants but black ducks do not seem to care for them during the fall months.

On the other hand, both water bulrush and Torrey's three-square bulrush were taken far beyond a point that their relative abundance would justify. Although listed as abundant, water bul-

rush is but one of seven plants rated thus, while the three-square is exceeded in abundance by several plants. These two species alone provided 75 per cent of the total fall foods in this area. Preference is certainly indicated in the case of these plants.

The same situation prevails with water bulrush and Torrey's three-square throughout many other sections of Maine and their importance is clearly shown in Table 1.

Wild rice and smartweeds were seldom eaten in the Pocamoonshine area even allowing for the fact they were not readily available, But data from areas where wild rice is abundant (some of which has been discussed in the preceding section) indicate it to be a favored food and one for which decided preference is shown. The Merrymeeting Bay data (about 20 per cent occurrence with nearly 60 per cent utilization) is the most outstanding example, but innumerable observations by the writer have indicated that when wild rice occurs in abundance black ducks apparently seek it out in preference to practically all other fall foods.

Smartweeds are likewise favorite fall foods in areas of abundance, although extensive smartweed beds are not common in Maine. During the spring season, preference for smartweed is shown even more strongly. On many marshes the few smartweed beds are sought out by large flocks of ducks and utilization of these plants is far beyond their abundance. Of course, high water levels of spring are conducive to feeding upon smartweed, but even so a definite preference is indicated.

Domestic grain appears to be a preferred spring food when present and when the birds have acquired a taste for it. Apparently the feeding upon grain by black ducks is a trait that has to be learned but once the habit is formed they find a ready and acceptable source of food among the waste grain in the flooded stubble fields during April and May. Data from Table 5 do not portray the true significance of this, but numerous observations in the State's principal grain section (Aroostook County) in northern Maine have lead the writer to believe that the presence of flooded grain fields in the river valleys has caused many pairs of black ducks to nest locally which might otherwise have continued their migration beyond this part of Maine which is rather barren of good marshes. The utilization of grain by black ducks in fall is probably more closely related to abundance than to deliberate choice. Yet even at this season an example of preference for grain may be seen in the fact that black ducks have actually been seen to dive for this food around baited areas or banding traps; several observers have reported such an instance and Kutz (1940) has recorded it in print.

As pointed out in a previous section, eelgrass appears to be a decidedly preferred food in coastal waters.

Several food items are difficult to interpret as to whether or not utilization is more a matter of preference than of abundance. These plants include the pondweeds, especially *Potamogeton natans*, and the bur reeds, *Sparganium chlorocarpum* and *S. fluctuans*. Much of the evidence would indicate preference. On the other hand the amount of bulk of such hard seeds as pondweeds and bur reeds found in duck stomachs can be slightly misleading. Their hard coats

will cause them to be retained longer in the gizzard than would be the case with soft seeds, tubers, or leafy material. It is likely that the bulk percentages as determined by stomach analysis of pondweeds, bur reeds, water lilies, snails and mussels are somewhat greater than the actual degree of utilization would warrant.

OTHER FACTORS

The four factors just discussed are believed to constitute those having the most effect on black duck food habits in a given marsh in Maine. A number of other factors also enter the picture, some of which are deemed of sufficient importance at times to mention briefly. Although availability of black duck foods is determined to a considerable extent by water levels, there are certain occasions when climatic factors may be of local or seasonal importance. A sudden freeze-up may result in an abrupt change in food habits, and an exceptionally severe winter may alter the normal feeding routine for a considerable period of time. Plant phenology will vary somewhat from year to year, and this in turn will be reflected in the diet of the south-bound migrants. Likewise a blight or an early frost will affect the abundance of the annual seed crop.

Apart from hunting, the element of human disturbance in black duck food habits is primarily seen in the industrial developments that have restricted waterfowl use of certain marshes. This is strikingly shown in many coastal areas and is believed partly to account for the present high utilization, in coastal habitats, of animal foods when present data are compared with the earlier study by McAtee.

One other factor appears worthy of comment. This is the feeding habit of diving ducks; in this State the ring-necked duck is of most importance although goldeneyes and scaups sometimes have a bearing on what black ducks will eat. The submarine activity of diving ducks often makes deep water plants available to blacks. The roots and tubers of some of the deep water pondweeds are often fed upon by black ducks after being dislodged by the divers. Even water bulrush, which thrives in a wide variety of water depths is undoubtedly a more important food to blacks because of the presence of ring-necked ducks. Except during very unusual water level drops, tubers of wild celery are only available when diving ducks dig them up. In fact, it seems likely from observations that wild celery might well be considered a preferred food under the somewhat infrequent conditions when it becomes available to black ducks.

ECONOMIC RELATIONSHIPS OF BLACK DUCK FOOD HABITS

RELATIONSHIP TO FISHERIES

Complaints have occasionally been made that black ducks cause damage to fishing interests. In Maine, hatchery attendants have sometimes claimed that black ducks fed upon fingerling trout and salmon in the rearing pools. Upon investigation, however, no damage of this type has been proven. Black ducks occasionally frequent rearing pools when these are in more or less isolated areas but in all instances known to the writer the feeding they do there is on material other than fish. Three black ducks were shot by hatchery personnel after they had been watched

feeding for awhile, supposedly on fishes. The stomachs of all three birds contained nothing but aquatic vegetation and insects. Possible damage by black ducks to fishing interests at hatcheries and rearing pools can be dismissed as either non-existent or negligible.

Commercial fishing interests in the North Atlantic have often claimed considerable damage to shellfish by black ducks, especially with respect to alleged depredations to clams. Although only a few such claims appear to have originated in Maine, a great deal of controversy on this point has been noted in Massachusetts during recent years, reaching proportions where it became a major issue in the fate of a Federal refuge established primarily for black ducks in that State. Since many of the coastal marshes and mud flats of Maine and Massachusetts are very similar, the findings of this study on black duck-shellfish relationships are of special interest.

In the fall months 49 specimens were obtained in coastal waters. As may be seen from Table 3, bivalves made up about 12 per cent of the food. Of this, only 1.5 per cent consisted of clams, chiefly a species of no commercial importance. The important species *Mya arenaria* was consumed to the extent of four-tenths of one per cent. The shrimps *Crago septemspinosus* which were eaten have no commercial value.

Of the 34 winter stomachs from the coast, bivalves were eaten in slightly greater amounts—13.7 per cent (see Table 4), but no trace of the commercial clam was found; nor was any other valuable shellfish consumed.

The data compiled by McAtee from Maine during the period 1909 to 1911 would indicate that black ducks of that era were not competing with the State's clam diggers any more than they are now. Of 101 fall and winter specimens the edible clams did not appear at all in the diet of the birds. Crabs did make up 3 per cent of the fall food of McAtee's birds; but crabs are used to only a limited extent commercially in Maine, and any damage to this industry is negligible.

It would thus appear that fishing interests in Maine, sporting or commercial, should have no complaints against the black duck.

CROP DAMAGE

In many parts of North America, relatives of the black duck, especially the mallard and the pintail, have sometimes caused considerable damage to agricultural crops. The grain-eating habits which the black duck occasionally shares with its relatives have, in a few instances, given rise to crop damage claims in Maine. Practically all such claims which have been investigated have been either exaggerated or have served as excuses to kill birds illegally. Only one claim is known to the writer during the past 12 years which was valid. In 1941, reports were received that a heavy concentration of black ducks was raising havoc in some of the grain fields in the St. John Valley in extreme northern Maine. The writer investigated this report as did a representative of the State Department of Inland Fisheries and Game. There was a concentration of birds along a 20 mile stretch of the St. John River that numbered nearly 2,000 at their peak around mid-October. This in itself was a rarity which even

the oldest inhabitants could not recall. Normally the peak concentration of migrating waterfowl of all species in the area seldom exceeds 300 birds. Many of the ducks were feeding on grain, as the reports had stated, but for the most part it was waste grain obtained in stubble fields which had already been harvested. In one instance, actual damage had occurred, and was still occurring when the investigation was made. An unharvested stand of buckwheat was almost completely consumed with a loss of several hundred dollars. But the loss had been due to unusual circumstances beyond the abnormal flight of blacks. The field was located on an island in the middle of the river. The river itself was almost at flood stage through heavy local fall rains and all aquatic food beds were too far under water to be accessible to the birds. To climax the set of unusual conditions which prevailed, the rains had so delayed the harvest that the owner of the field had barely started cutting grain when the potato crop was ready for digging and all grain harvesting was stopped.

Since 1941, the writer has made annual trips to the St. John Valley for the express purpose of obtaining crop damage data, but none of any consequence has been forthcoming. The birds feed on grain rather extensively at times but it is practically all waste grain obtained in the stubble fields. In northern Maine grain is raised primarily because of its use in rotation with potatoes which is the chief crop of the section. For this reason, except when adverse weather prevails in late August and early September, the grain is cut before the potatoes are dug. Thus the grain is normally harvested long before the migrating black ducks come in.

Another factor which minimizes even potential crop damage in Maine is that only a relatively small proportion of the black ducks frequenting the St. John Valley actually are "grain field birds." As was pointed out previously, all evidence obtained in this study points to the fact that black ducks have to acquire a taste for grain and apparently the majority do not do this.

From 1941 to 1946, 29 black ducks were collected in the upper St. John Valley, all at times when birds were known to be feeding at nearby grain fields. Three were actually shot in grain fields but the majority were obtained at known resting areas so as to better insure full digestive tracts. Even though this phase of the study was partially selective (favoring evidence on the consumption of grain) it was interesting to note that of the 29 stomachs, only 8 contained grain, while the remainder contained aquatic foods. Grain made up a total of 23.7 per cent of the diet of the 29 birds. Even black ducks collected under identical conditions and frequenting the same rest areas often showed little similarities in their feeding. One morning in mid-October the writer sat in a blind at the edge of a cove in the river which was used for between-feeding resting. Two black ducks came down river together, flying high. They circled the cove several times always side by side. Finally they came in over the decoys and both were shot. It could be expected that the stomach contents of these birds would be similar but such was not the case. Ninety-nine per cent of the stomach

contents of one consisted of buckwheat; the other bird had fed entirely on seeds of bur reed and tubers of arrowhead!

Of the grain eaten by black ducks in Maine there is little preference exhibited between oats, buckwheat, or barley. The proximity of the grain field to water appears to be the chief factor in determining which grain will be eaten if more than one kind is available.

Considering all the evidence obtained in this study it may be said that while grain is a favorite food for a small proportion of Maine black ducks, practically all of it is waste grain. Actual crop damage occurs only under unusual conditions and need cause little concern to agricultural interests of the State.

FOOD HABITS AND MANAGEMENT OF THE BLACK DUCK

In any program for waterfowl management a full understanding of food limitations is important. It is believed that the present study points the way toward the improvement of many marshes in the northeast from the standpoint of greater production of black ducks. There is no reasonable limit to potential breeding grounds in Maine and New Brunswick. The statement has often been made in recent years that since breeding grounds in the northeast are greatly underpopulated at present, little can be done by way of their management that will be effective. Our interpretation of the studies in Maine do not agree with this premise. Low productivity of the breeding marshes in this region is certainly a limiting factor in the continental black duck population. Productivity cannot be increased much in some areas where water rights are controlled by utility interests and where nesting losses from floods are often extremely high. On many marshes, however, productivity can be increased considerably through management. Such population increases will not be rapid because the black duck does not regularly nest in concentrations but even modest increases in breeding ground productivity will eventually have an effect on populations. Management studies which the Maine Cooperative Wildlife Research Unit is carrying out have already indicated that an effective means of increasing productivity and, in turn, population is to locate a managed marsh near unmanaged ones—especially when the latter are subject to disastrous water fluctuations. The over-all study of black duck management is still incomplete but enough information has been obtained on the food habits phase so that specific recommendations can be made.

A lack of food is not a direct limiting factor to black ducks in the northeast. The birds are unusually adaptable in their dietary choices, probably more so than any other species of Maine waterfowl. Their range of potential foods is so great that some item is almost certain to be available to them at any season of the year and under any climatic conditions, barring of course the freezing of the coastal bays. Even when this occurs, as in the winter of 1947–48, actual losses due to starvation do not appear to be excessive. The hardiness of the black ducks that winter in the northeast is apparent to all who have studied them.

However, in spite of its adaptability, only a relatively few foods are high on the preferred list of the black duck and, when present in large quantity, such

foods are deliberately sought out. It is only logical to suppose that the provision of these foods in otherwise acceptable breeding marshes will constitute a successful step in black duck management.

CONTROL OF WATER

Unless water levels can be controlled and proper interspersion of water, marsh, and land provided in a given area, it is better to dispense with any efforts at building up breeding populations. Several instances have occurred in Maine where extensive food plantings have apparently increased the breeding stock only to have the "managed" area become a veritable death trap through unfavorable and uncontrollable water levels that resulted in excessive predation or flooded nests. These management efforts may have decreased rather than increased the population.

Aside from direct lethal effects of unfavorable water levels on the breeding grounds, the plants which might be introduced into a marsh depend upon certain water levels for optimum growth and production of seeds or tubers. Thousands of dollars have been wasted by sportsmen's clubs and private individuals through the planting of waterfowl foods in waters which were not adapted for the plants or where excessive water fluctuation occurred. During the experimental food planting program carried out by the State Federal Aid Division, one of the most successful establishments of wild rice and floating-leaved pondweed occurred on a marsh in south-central Maine. In two years the wild rice had attained height and density of growth approaching rice stands of the Lake States—a condition seldom attained anywhere in New England. But the third year individuals holding water rights drew the water almost completely out of the area in July and kept the levels down until September. The planting program was practically ruined as a result. Management without water level control has slight chances for consistent success.

PLANTING PROGRAM FOR MAINE'S INLAND MARSHES

If water levels can be controlled on a marsh the following planting program, in areas where surveys have indicated a need for such steps, should be expected to produce desirable results. The planting list is not extensive and contains no "exotics."[3] There appears little justification for trying to establish aquatic vegetation that is not native to this region and which might not even be utilized by black ducks if it could be induced to grow. Recommendations are here made with the aim of improving *breeding* marshes in the interior of the State. Although the nesting potentialities of Maine's salt marshes and coastal islands have not been fully studied, there is little doubt but that they are relatively unimportant compared with the inland waterways. Therefore, the planting recommendations are based upon supplying any deficiencies among seasonal preferred foods to supplement the variety of other foods that will certainly be present in the particular marsh anyhow.

[3] Wild rice might be considered an exotic species by some authorities, although it has been present in parts of Maine for upwards of 100 years.

Bur reeds. The bur reeds are all-season foods for black ducks comprising the only plant group which was extensively used from early spring to late fall. Although the seeds may not rate so high on the preferred list as several other items, they constitute a desirable and acceptable food. The emergent bur reed *Sparganium chlorocarpum* is the most important species in Maine and is especially recommended for shallow water areas where a cover deficiency may exist, as the plant has high cover value as well as food value.

For open water areas such as coves, potholes, and back channels, the floating bur reed *S. fluctuans* is recommended. Although lacking the cover value of the preceding species the seeds are more extensively used during summer and are of greater importance to the young birds.

Bulrushes. The two species of bulrushes which provided quantities of tubers to the birds examined in this study, *Scirpus subterminalis* and *S. torreyi*, should be introduced into managed areas where they do not occur and where conditions are favorable for them. Too many planting programs in the past have paid scant attention to the providing of tuberous foods and have been concentrated primarily on introducing species providing only seeds. The starchy bulrush tubers undoubtedly fill a much needed nutritional requirement for black ducks, especially as fat producers in late summer and fall.

The submerged form, water bulrush (*S. subterminalis*) is an open water plant suitable for rapidly moving currents or stagnant potholes alike. It thrives in water from a few inches to several feet in depth and will grow on bottoms ranging from soft ooze to hard clay.

The emergent three-square bulrush (*S. torreyi*) is much more exacting in its habitat requirements but has a very desirable place when it can be used. It grows best in from 2 to 10 inches of permanent water and can be used to advantage in the border between open water and the drier portions of the marsh.

Pondweeds. Three species of pondweeds—*Potamogeton natans, P. epihydrus*, and *P. pusillus*—are recommended for use in the northeast. The first mentioned is apparently most preferred by black ducks and is very tolerant to highly acid waters as well as variable bottom types. *P. epihydrus* is especially desirable for deep waters and those having a moderate current. It is very acid tolerant. *P. pusillus* is a good pothole and back channel plant where waters are shallow. In addition to the seeds, the root structures of this species are sometimes heavily utilized by the birds.

The pondweeds have an indirect additional value in that they harbor quite an abundance of insect life—an important part of the summer diet, especially of the downy young.

Smartweeds. Smartweeds apparently constitute a preferred spring food of black ducks, and they are also very useful in fall during high water or in marshes where it may be desirable to raise water levels in late summer or fall. Only the marsh species are recommended for management planting to correct spring food deficiencies although the aquatic form *Polygonum hydropiperoides* establishes good beds in many areas of Maine. The species sug-

gested for planting are *Polygonum pennsylvanicum*, *P. sagittatum*, and *P. hydropiper*.

Wild Rice. In spite of the fact that wild rice (*Zizania aquatica*) is often over-rated as a duck food, being important for only a few weeks out of the year, it is a very valuable plant in a managed area. When abundant it is highly preferred by the birds, its starchy seeds are an excellent fattening food on which the ducks can stuff themselves prior to fall migration, and it affords good cover late in summer and during early fall. When water and soil conditions are favorable wild rice will grow in dense stands in the northeast. It is not tolerant of highly acid waters or those having ooze bottoms, however. Wild rice is an important "holding" food and when well established on breeding refuges can undoubtedly be of great importance in forestalling early migration; thus considerable saving of breeding stock from early season shooting could be expected.

Grain. Domestic grains such as oats, buckwheat, or barley, are apparently fairly high on the preferred list of black ducks in spring, where grain fields are adjacent to water. In a managed area the planting of grain patches around the marsh, especially in flat land where melting snows will leave pools on the fields is recommended. Such a procedure might well prove an important step in enticing migrating birds to remain in the marsh until nesting time.

Pickerel Weed. Pickerel weed (*Pontederia cordata*) is recommended as a plant to be considered strongly in breeding ground management of the northeast. It is not an important food but it is utilized somewhat in late summer and early fall, apparently more so than the stomach examinations show. But its value as a source of insect foods is very great. Furthermore, our observations indicate that it is one of the most important plants in our marshes from the standpoint of brood cover and molting cover. In southern New England and even in extreme southern Maine it may grow so rank as to become a nuisance species and it should be introduced with care, but in northern New England and southeastern Canada it fills an important niche in the breeding marshes where it occurs. It is adaptable to acid waters, stagnant or moving, and soft and moderate bottoms. It grows best in less than 18 inches of water. In planting, it is recommended for the border of the open water areas.

Water Shield. If pondweeds, pickerel weed, and water bulrush are abundant in a breeding marsh, it is probable that the insect requirements of young black ducks will be adequately met. In the event that there is believed to be any deficiency in such foods or if considerable expanses of open water exist which cannot be planted to the foregoing species a limited amount of planting of water shield (*Brasenia schreberi*) may be desirable. Any of the members of the water lily family are excellent sources of insect food. Unfortunately neither the white nor yellow water lilies provide any appreciable food through their seeds, whereas the seeds of water shield are consumed to some extent by the birds. A more important consideration is the fact that the white and yellow lilies often become nuisance species occupying valuable space in the marsh—a trait which is much less

common to water shield. It often grows in bottoms that are too oozy for pickerel weed and pondweeds and its chief justification for use would be under such conditions.

It is not within the scope of the present paper to discuss planting techniques in connection with marsh development, and several publications are already available that deal with this subject.

SUMMARY

As one phase in a black duck research program, a food habits study was carried out in Maine from 1938 to 1946 inclusive. A total of 605 stomachs was collected. All seasons of the year were represented. Data were classified according to the three general habitat types used by Maine black ducks at various times of the year: (1) inland fresh water, (2) inland tide water, and (3) coastal water. Stomachs were obtained in fall from all three habitat types since each is used extensively by the ducks. Winter collections were made in the open coastal waters which constitute the black duck winter habitat. Spring and summer collections were confined to fresh waters, which are of most importance to breeding birds.

Leading fall foods were found to be as follows, in the order of their importance:

Inland fresh water—(1) bulrushes (chiefly water bulrush, and Torrey's three-square bulrush); (2) bur reeds; (3) pondweeds; (4) wild rice. *Inland tide water*—(1) wild rice; (2) various emergent bulrushes (eight species); (3) pondweeds. *Coastal water*—(1) snails; (2) pondweeds (eelgrass and widgeon grass); (3) mussels and non-edible clams; (4) amphipods.

The winter food was made up largely of animal organisms, with snails predominating. Other foods eaten in appreciable amounts were mussels and non-edible clams, and amphipods.

The most important spring foods were found to be sedges, bur reeds, smartweeds, and spike rushes. Over 90 per cent of the spring food was of vegetable material.

Summer food of adult black ducks and of young birds over half grown was largely vegetable material, with water bulrush, Torrey's three-square bulrush bur reeds, and wild rice being of most importance. The downy young had fed extensively on animal food—insects, snails, and fresh water clams being utilized heavily; the only plant foods of importance to the small birds were pondweeds and wild rice.

Food habits of the black duck in Maine are influenced by several secondary factors and by the following four major factors: water levels, food abundance, food preference, and hunting pressure. Of these, water levels are of most importance and are closely related to most of the other factors.

The economic relationships of black duck food habits were found to be very satisfactory. Damage to fishing interests is negligible. Crop damage may occur under rare conditions but is of practically no importance to Maine agriculture.

It is believed that effective management of black duck breeding grounds in the northeast is possible on many of the marshes located there, *provided that water levels can be stabilized.* An impor-

tant step in such management is the improvement of food conditions where deficiencies occur. Based on the findings of the present study, a planting program is recommended for inland breeding marshes which involves those species definitely preferred by black ducks or readily eaten by them and which provide varied foods for spring, summer, and fall.

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THE CROWING COUNT PHEASANT CENSUS

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The crowing count in its present form is not presented as a finished pheasant censusing technique; to date it is not a census method but a population index. However, it is believed to be the most accurate index and it can be applied equally well to a small area or an entire state, and to a low as well as to a high pheasant population. It also shows the greatest promise of being developed into a true pheasant census. The work in its present form is published because of the method's value as an index and because applications by other workers may shorten the time necessary for it to become a census method.

The data contained in this paper are derived from four years' work; one year in Nebraska (Pittman-Robertson Project 15-R), one in Minnesota (P.R. Project 11-R), and two (the most extensive) in South Datoka (P.R. Projects 17-R and 18-C). The sample includes 304 mornings' work, 5,989 two-minute counts, and 162,940 cock calls recorded.

PROCEDURE USED IN CONDUCTING A CROWING COUNT

1. Locate representative twenty-mile routes throughout the area to be censused. The number of routes needed can be roughly established by determining the number of man mornings which can be allocated to the job for a period of six or eight weeks, and reducing this by the estimated average number of mornings when the wind at sunrise will exceed 8 miles per hour. All-weather roads should be used when possible but highways which may have early morning traffic should be avoided. Telephone lines, especially large numbers of them, should also be avoided when possible because of their distracting hum in light wind.

2. Establish at least one, and preferably two or more check routes. These can be regular routes which are selected on the basis of convenience, good roads, and lack of interference noises. The purpose of these routes is to determine the dates between which regular routes can be run. Starting early in the crowing season, sometime in March for the northwest, they should be run twice a week until censusing starts and, if time permits, they should be run weekly throughout the censusing season. This will provide a correction factor if one is needed.

3. In determining the time of day to start the run a good rule of thumb is to begin as soon as you can read the second hand on your watch by natural light but never earlier than one hour before sunrise. However, 40 to 45 minutes before sunrise will seldom be wrong.

4. In making the run the procedure is as follows: stop the car, shut off the motor, get out and walk at least 15 feet away, stand perfectly still and count cock calls for exactly two minutes. Get back in the car, record the count, drive one mile and repeat the same procedure. Continue this for 20 stops.

5. Compilation of the data after the field work has been completed provides an index to the spring cock population. This index in itself has considerable value but it also serves as a basis for determining other population characteristics through the application of ratios. The following simple formulas show the derivation of total population indices at two times of the year.

$p = C + CH$

$P = C + CH + CHY = C(H + HY + 1)$

p = Spring breeding population index

P = Post-breeding population index

C = Cock calls per 2 minutes

H = Hens per cock

Y = Young per hen

DISCUSSION OF PROCEDURE

Check stations, that is, counts taken from a single location, may be somewhat better than the routes for determining the daily duration of maximum crowing. However, stations are believed less reliable for determining the proper dates of censusing. Bird movements and possibly other factors may alter crowing intensity at any single station. Daily duration of maximum crowing can be quite well determined from the check route if care is taken to stop at the same time and places on the route each morning. The date of near maximum crowing intensity will be determined by two factors. The total counts on the check route will level off, and near maximum crowing will continue for the 80 to 100 minutes necessary to

run a route. When the first and last few counts on the check route do not show marked variation for a week and a half censusing can begin.

Winds of 8 miles per hour or over make it impossible to get maximum counts. By facing at right angles to the wind direction the amount of whistling in the ears will be reduced.

After considerable experimentation the two-minute period has been chosen because it appears to give a quite reliable sample even in very low populations, because time is limited, and because it is difficult to concentrate for a longer period. Concentrating on the one sound is not easy and requires some practice. It is helpful either to close the eyes or look at the ground.

Apparently almost anyone with normal hearing can learn to take crowing counts but it does require practice. The men who are to make the census should work together for a few mornings or evenings before work is started. An inexperienced worker will usually have low counts at first, and this is often followed by excessive counts due to misinterpretation of other sounds or to imagination. By the time he has taken ten or twenty counts he will, in most cases, be hearing almost the same number of calls as the experienced worker.

Interference noises are always a problem. Before the route is half run the song birds will start their chorus; farm house doors will be slammed; farm poultry will start cackling, crowing, and honking; dogs will bark; and worst of all, some sunrise farmer will start his tractor. At first these sound interferences are a serious distraction but as the worker learns to concentrate on the pitch of a pheasant call the problem becomes less serious. Apparently tractor noises cover the entire scale and obliterate calls. When interference is known to have reduced the count this should be marked on the tally sheet or, in some cases, the count should be omitted or retaken one-half mile down the road.

It is not necessary to stop at exactly one mile intervals. Sound barriers, as well as interference noises should be avoided when possible. If the area is checked with section line roads it is usually advisable to avoid stopping at the section corners where farm buildings are most apt to be located.

Only the regular two-syllable crowing of cock pheasants should be counted. However, regular calls from a distance seem short and of one syllable. Hen calls and the drawn out *"cuh cuh cuh"* of cocks should not be recorded.

It is important to complete the run as quickly as possible, therefore no time should be wasted in driving the mile between stops. A heavy foot on the accelerator for nine-tenths of a mile and on the brake for one-tenth is recommended. The car door should not be slammed. This may stimulate crowing for a few seconds and be followed by a lull.

Winter appears to be the best time to obtain pheasant sex ratios for use in the formulas. Flushing pheasants from concentration areas during periods of severe weather appears to supply reliable sex ratio data. Such counts are reliable only during storms or on very windy cold days following mild weather. At this time all birds appear to be in concentration. During milder weather cocks leave the concentration areas and the count will run heavy to hens.

If winter sex ratios have been determined, an index to the total spring breeding population can be calculated as soon as the crowing count is completed. A spring population index is of value in predicting fall populations, estimating possible spring damage to farm crops, determining the time and extent of mortality, and studying other population characteristics.

In completing the formula for the midsummer population, ratio data are obtained from the roadside count and the rural mail carrier survey (an adaptation of roadside censusing). An increase in the sex ratio because of high hen mortality in the nesting period may take place between winter and midsummer. Therefore, the (H) factor used in determining the spring population index (p) should probably be reduced in determining the post-breeding population index (P). For lack of accurate information on the change in sex ratio this has not been done in South Dakota. As long as the crowing count is used as an index method only, correcting for a change in sex ratio is not essential unless it is determined that this change varies considerably from year to year. It will no doubt, vary with locality and farming practices.

The (Y) or young per hen factor in the formula is determined by application of a correction factor to summer surveys. It is known that young per hen ratios as determined in late summer are always low because even when broods are flushed not all of the young are seen. Therefore, a correction factor should be applied to the young per hen ratio to obtain the desired (Y) for the post-breeding population formula (P). This is determined by checking the "observed" young per hen ratio against the young per hen ratio found in the hunters' bag. The largest sample of "observed" age ratio data in South Dakota is obtained from the rural mail carrier survey so this is used in determining (Y) in the following manner.

Between July 22 and 27, 1946, mail carriers recorded 8,764 hens and 20,058 young for a young per hen ratio of 2.29. Later, during the hunting season, 2,016 hen pheasants were checked for age. It was learned that 780 were adults and 1,236 were juveniles for a female age ratio of 1.57 young per adult. The sex ratio of adults was very close to 100 (equal) and the age ratio of 4,880 cocks checked was 1.51 young per adult. Thus, it appears safe to assume that each hen brought a similar number of young cocks and young hens to the hunting season. Therefore, the number of young hens per adult hen (1.57) is doubled to determine the number of young birds each hen brought to the hunting season. Two times $1.57=3.14$ which is the figure used for the 1946 young per hen ratio in the hunters' bag. Dividing the kill ratio of 3.14 young per hen by the observed ratio of 2.21 we obtain a correction factor of 1.42. This will vary somewhat from year to year but an average will be obtained and used. A method of reducing the variability of this correction factor will be discussed later. Following is an example of how the post-breeding population formula $P=C\ (H+HY+1)$ was worked out for South Dakota in 1947.

$C=48$ calls per 2 minutes
$H=1$ hen per cock
$Y=3.59$ (young per hen ratio by rural mail carriers of 2.53 times the 1.42 correction factor)
$P=48(1+3.59+1)=268.32$.

In 1946 the corrected "*Y*" could not be determined until the hunting season because it was the first year and no correction factor for "*Y*" was available. However, in 1947 the post-breeding population index "*P*" could be worked out for both years. Following is the 1946 formula.

$C = 59$ cock calls per 2 minutes
$H = 1$ hen per cock
$Y = 3.14$ young per hen as determined by bag checks
$P = 59(1+3.14+1) = 303.26$.

Thus, the population index declined from 303.26 in 1946 to 268.32 in 1947, a reduction of 11 per cent.

The decline in birds seen per mile shown on the roadside count and rural mail carrier survey was approximately 25 per cent. This figure is now known to have shown too great a decline because, though these surveys were run on the same date in 1946 and 1947, nesting was delayed by an extremely late spring in 1947 and the number of birds counted was considerably below what it would have been a week or two later. This error in timing introduced a large error into the results of the two surveys, depending upon seeing the birds. It also introduced an error, though a much smaller one, in the population index determined through crowing counts because the young per hen ratio (Y) was to low to be compensated for by the 1946 (Y) correction factor of 1.42.

Some method of determining the proper time for conducting all types of roadside surveys each year is badly needed. This could probably be accomplished through annual study of physiological changes such as gonad weights or ovary development. This, however, would involve collecting a fairly large sample of birds. Spring crowing count data as plotted in Figure 2 can very probably be used to determine the proper dates for running roadside surveys. This will not only improve the accuracy of these surveys but, by reduced variability in the accuracy of obtaining the young per hen ratio, the correction factor for (Y) will become more constant and the crowing count population index will be determined with greater accuracy. Roadside surveys should be conducted at a definite number of days following the time when seasonal crowing activity (Figure 2) reaches near maximum and levels off. This should greatly reduce the variable factor which is believed to have introduced the greatest error into all types of roadside survey; that is, the factor of not conducting the survey at exactly the same point in the reproductive cycle of the pheasant each year.

The period between the beginning of near maximum crowing and the start of roadside surveys may necessarily vary between states because the date when recommendations for setting hunting seasons differs between states. However, as long as this period is constant from one year to the next it will not affect the accuracy of the population index. Where roadside surveys are made too early for maximum young counts the correction factor for (Y) will be greater. It would be more desirable if a standard period between the time when crowing approaches maximum and the start of the roadside survey was accepted by all workers. Additional study will be needed to determine what this period should be but available data suggest 14 weeks as a minimum.

There is at least one other method of

determining the proper dates for taking roadside surveys. This is through a study of spring "observed" sex ratios. In the spring there is a short period after the hens have dispersed from concentrations, and before nesting actually begins, during which a maximum proportion of hens is apparent. All small game research personnel in South Dakota record pheasants seen on prepared sight record forms. Through this study of populations it was learned that the lowest observed sex ratio was during the week of May 5–11 in 1946 and May 11–17 in 1947. Thus, the period when most hens were apparent was a week later in 1947.

As hens start incubating and are seen less frequently the "observed" ratio rises. In 1946 the highest sex ratio was recorded during the week of June 23 to June 29 compared to June 30 to July 6 in 1947. Here for the third time we find data to show the reproductive cycle occurring one week later in 1947 than in 1946. This information was not recognized in time or our roadside surveys would have been run a week later in 1947 than in 1946. It seems strange that we have conducted the roadside census for so many years without annually correlating the time it should be taken wtih the progress of the reproductive cycle, and thus eliminating a major source of error.

From the above discussion it may appear that obtaining the sex ratio and the young-per-hen ratio necessary to compute the post-breeding population index presents a difficult problem. This is true, but it is information necessary to the study and management of any species regardless of what census method is used. However, it is realized that where the sex ratio is not known and hen pheasants are not taken during the hunting season it is impossible to obtain an age ratio of the kill figure which is of any value. The crowing count still supplies a reliable spring population index. Some method of determining spring reproductive success is always necessary and this, used in conjunction with the number of calls per 2 minutes, provides an index to the fall population. A young per hen ratio can be obtained by flushing all hens and broods seen. This can, if desired, be used directly in the formula without applying a correction factor. A good year to year population index will still be attained.

ACCURACY DETERMINANTS

The accuracy of the crowing count and the success with which it can be used are dependent largely upon the following factors:

1. Variation in ability of the individuals conducting the survey to hear cock calls.
2. Daily trend and duration of maximum cock crowing.
3. Seasonal trend and duration of maximum cock crowing.
4. Uniformity of results.
5. Effect of variable factors, such as weather and cover, upon the count.

VARIATION IN ABILITY TO HEAR COCK CALLS

During the past three years 6,453 cock calls have been recorded simultaneously by two or more experienced observers. Table 1 shows the results of these records.

If the data in Table 1 showing an average coefficient of variation of 1.5 per cent are representative it is obvious that no appreciable error can be antici-

pated through lack of uniform results obtained by experienced workers. No data are available on the uniformity of results obtained through ocular observations but it seems very unlikely that such uniformity of results could be obtained. Surveys such as a roadside count demand normal eyesight plus alertness and concentration for a continuous period of an hour or more. Crowing counts require normal hearing and concentration for twenty periods of only 2 minutes duration. The latter should yield more uniform results.

TABLE 1.—VARIATION IN 2 MINUTE CROWING COUNTS TAKEN SIMULTANEOUSLY BY TWO OR MORE INDIVIDUALS

Name	Year	No. of Counts	Ave. Count	Standard Deviation	Coefficient of Variation
Stiehm	1945	40	43.7	14.0	.8
Kimball		40	44.4		
Parker	1945	9	11.4	4.0	3.7
Kimball		9	12.3		
Stiehm	1945	8	22.4	2.9	1.6
Kimball		8	22.1		
Schrader		8	21.5		
Nelson	1946	34	42.1	21.5	1.5
Kimball		34	40.9		
Huff	1946	19	50.8	6.0	.6
Trautman		19	51.5		
Nelson	1946	20	101.1	1.0	.0
Huff		20	101.2		
Nelson	1947	20	66.2	33.5	2.6
Banko		20	62.8		
Total		150			
Average			46.3		1.5

DAILY TREND AND DURATION OF MAXIMUM CROWING BY COCK PHEASANTS

Curves of daily crowing intensity have been plotted for a number of stations and check routes. However, data obtained from a single route are not desirable for this purpose because the population density will vary along a twenty mile route. Data obtained at single check stations during the seasonal peak of crowing have not been large because the stations are often neglected at this time in order to obtain statewide data. It is also possible that stations may not show a true trend of daily crowing intensity because of cock movements from roosting areas to crowing territories. This appeared to take place in at least one instance.

Figure 1 is believed to show a fairly reliable picture of daily crowing intensity. The fact that it is compiled from 58 routes practically eliminates the possibility of error caused by population variation along any one route.

Figure 1 shows only the portion of the

daily crowing intensity curve which is of value in taking a census. Prior to 40 or 50 minutes before sunrise the curve rises abruptly from 0 at approximately 60 or 70 minutes before sunrise. However, limited crowing may be heard in bright moonlight at almost any hour of the night. Following 60 minutes after sunrise the intensity of crowing falls more gradually than it rises but counts beyond this point are subject to greater deviation than during the period plotted on the graph.

Fortunately crowing intensity between −40 to +50 minutes is relatively constant, the maximum variation being ±7.5 per cent of average. A correction factor could easily be computed from the curve to be applied at 10 minute intervals. This would be of value when maximum accuracy is needed in working a limited area intensively, but seems unnecessary when each route is run during the same period of time. If the crowing count is eventually used as a true census rather than an index, correction factors may be essential.

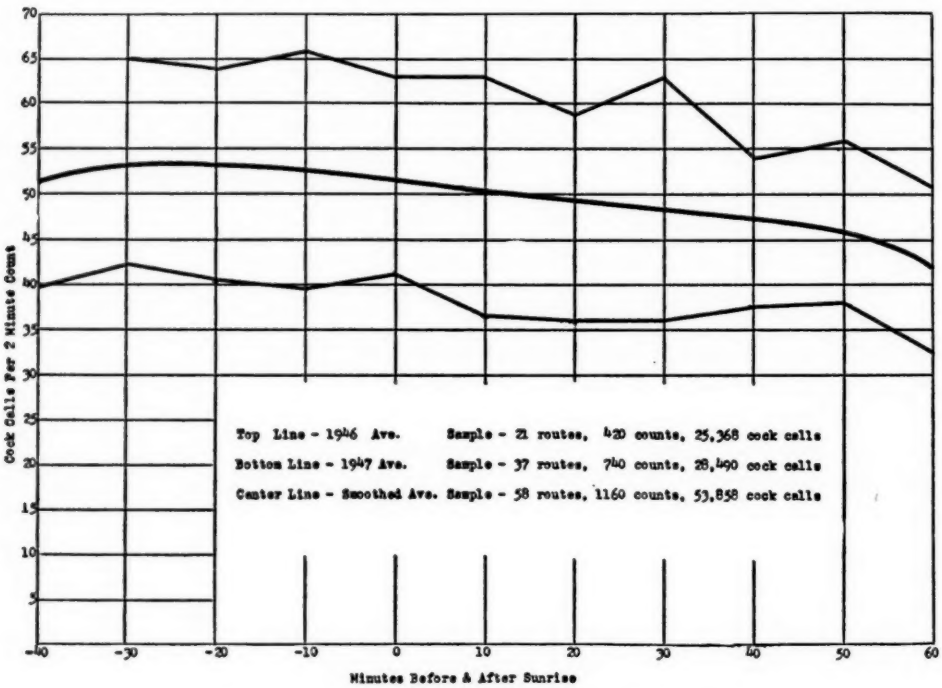


FIG. 1.—Relation between time before and after sunrise and number of calls per two-minute interval.

SEASONAL TRENDS AND DURATION OF MAXIMUM COCK CROWING

As previously stated, check routes and stations tend to be neglected when the period for state-wide censusing is proved to be at hand. This fact has resulted in insufficient data to plot with great accuracy the seasonal trend of

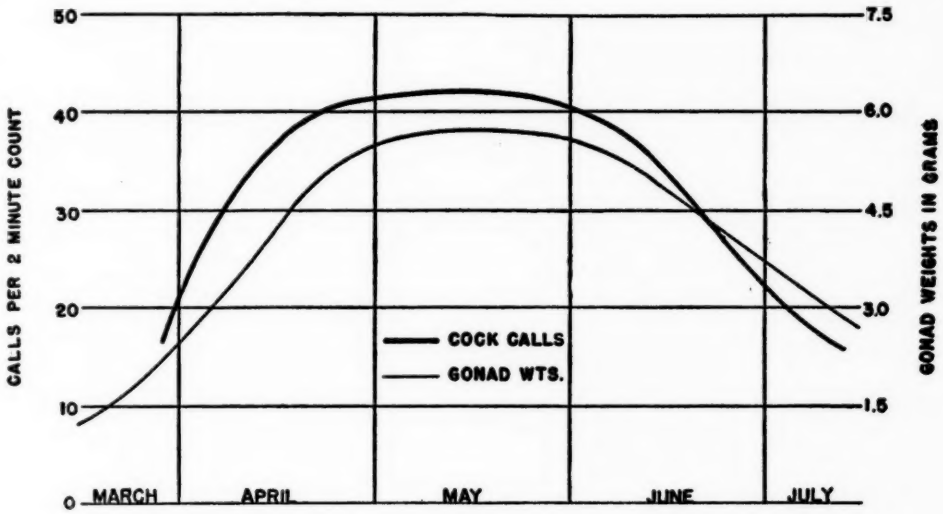


FIG. 2.—Graphic representation of seasonal relationship between cock calls per two-minute interval and weight of testes.

cock crowing intensity.

Eight routes or check stations show various portions of the seasonal crowing curve. However, they have been taken over a three year period in three states, and too few show the complete crowing trend throughout the entire season. The upper heavy line in Figure 2 is a smoothed curve of seasonal cock crowing as determined for South Dakota in 1947. It is derived from the combined data of the Brookings County station (13 mornings) and the Davison County route (15 mornings). Only the smoothed curve is plotted as the deviations are shown statistically in Table 2.

It should be emphasized that Figure 2 shows seasonal crowing activity only for South Dakota and only for the year 1947. The shape of the curve should remain the same but its position may vary annually and it may vary with geographic location. However, Smith (1947) shows a very similar curve of

TABLE 2.—DEVIATIONS IN 2 MINUTE CROWING COUNTS TAKEN AT THE SAME STATIONS OR ROUTES ON VARIOUS MORNINGS

Location	Dates	Type	No. of Days	Ave. No. Calls Per 2 Minutes	Standard Deviation	Coefficient of Variation
Winona Co. (SE) Minn.	4-12 to 6-12 1945	Route	5	2.3	.22	*9.6*
Redwood Co. (W) Minn.	3-31 to 4-17 1945	Station	8	89.9	7.39	*8.3*
Redwood Co. (W) Minn.	4-27 to 5-17 1945	Route	5	56.4	4.73	*8.4*
Beadle Co. (E. Cent.) S. Dak	4-15 to 6-21 1946	Station	3	84.0	7.79	*9.3*
Brookings Co. (E) S. Dak.	4-29 to 6-14 1946	Route	4	19.1	2.00	*10.5*
Davison Co. (S) S. Dak.	4- 7 to 6-12 1947	Route	9	47.6	5.84	*12.3*
Sully Co. (Cent.) S. Dak.	4-12 to 4-28 1947	Station	3	82.0	1.92	*2.3*
Brookings Co. (E) S. Dak.	5-12 to 6-12 1947	Station	4	35.8	2.42	*6.8*
Total			41			
Average					4.04	*8.44*

crowing activity in Utah. The decline of crowing activity in June seems to be relatively constant each year but the time at which near-maximum crowing is reached in spring appears to vary to a greater degree and may correlate with early spring weather.

Crowing apparently started earlier from 1944 to 1946 than in 1947. This could have been caused by unusually inclement weather during the spring of 1947. In some years counts have been reliable as early as the first week of April.

The relatively flat top exhibited in the curve (Figure 2) is, of course, an important factor in making the crowing count possible, in that it gives sufficient time to carry out the field work. Schwartz (1945) shows a more cone-shaped curve exhibited by the activity of male grouse on the spring booming grounds. He states that the morning period of greatest activity is, "... from 15 minutes before sunrise until an hour and 15 minutes after sunrise during the climactic week of the season and the weeks immediately preceding and following it."

During 1946 and 1947 gonad weights and measurements were taken on 160 cock pheasants. The important part of the curve constructed from these weights has been plotted in Figure 2 (lower light line). These data show that a close correlation exists between the gonad weights and cock crowing intensity. It seems possible that the period for conducting the census may be determined, in part at least, by gonad weights of cock birds. The examination of cocks killed along highways could furnish at least part of the sample.

The two most apparent explanations for the relatively flat topped curve exhibited by cock crowing are as follows. First, pheasants are persistent renesters. Breeding activity may therefore remain high for considerable time. Secondly, the crowing activity curve in Figure 2 shows what is needed for censusing and is somewhat more flat topped than the gonad weight curve. It does not depict all phases of mating activity but represents only crowing activity during a 90 minute period. Indications are that peak crowing intensity continues for considerably more than 90 minutes during the height of the season and is of shorter duration prior to and following the peak.

From Figure 2 it is determined that crowing counts taken over the six week period of maximum crowing would contain an error due to seasonal variation in crowing of only ± 3 per cent.

UNIFORMITY OF RESULTS

The uniformity of results obtained by running a single census route or check station several times is shown in Table 2. Comparable data are shown for the roadside census in Table 3.

Table 2 shows that on 8 routes or check stations the crowing count coefficient of variation (standard deviation expressed in per cent) varies from 2.3 per cent to 12.4 per cent for an average of 8.4 per cent. These counts were made as early as March 31 (1945) and up to June 21 (1946). This is stretching the recommended counting period but the variation was not materially increased by using these early and late data. Early counts in 1947 could not be used.

The condensed data from the 15 roadside counts made by game techni-

cians in 1947 are shown in Table 3. The bulk of South Dakota's roadside counts are made by wardens, but to compare data from the same source only counts made by technicians were tabulated.

TABLE 3.—DEVIATION IN ROADSIDE COUNTS TAKEN OVER THE SAME ROUTES ON THREE MORNINGS DURING THE LAST TWO WEEKS OF JULY, 1947

Location S. Dak. County	Ave. Count Per Run	Standard Deviation	Coefficient of Variation
Bon Homme	17	2.5	*15.1*
Campbell	46	24.2	*52.6*
Clark	11	2.9	*27.1*
Corson	15	12.1	*80.6*
Hand	11	3.1	*28.2*
Jerauld	21	7.1	*33.8*
Lyman	11	7.6	*69.1*
Lyman-Jones	11	1.9	*17.3*
McPherson	35	13.2	*38.1*
Meade	6	3.6	*59.3*
Mellette	11	6.2	*56.0*
Perkins	14	4.2	*30.1*
Potter	41	19.3	*47.1*
Sully	61	24.3	*39.8*
Turner	11	.6	*5.2*
Average	21	8.9	*40.0*

The coefficient of variation for the crowing count (8.4 per cent) compares very favorably with the average figure of 40.0 per cent shown for the roadside count in Table 3. Fisher, Hiatt & Bergeson (1947) also found high variation in their study of the roadside census. They state, "Fluctuations often exceed several hundred per cent in successive periods." However, the purpose of this paper is not to condemn the roadside census. Comparisons are made only to show the relatively greater accuracy attainable through crowing counts, and in South Dakota the crowing count and the rural mail carirer survey are both supplying more accurate pheasant population indices than the roadside count.

The accuracy of the crowing count shown by the low coefficient of variation is undoubtedly due in part to the large sample obtained. In 1947 crowing counts and roadside counts were run over the same route in 51 instances. Comparison of results are made in Table 4.

Table 4 shows first that crowing counts yield a sample roughly 75 times that of roadside counts. The time and expense of conducting either of the counts is approximately the same.

The data in Table 4 were divided into routes of "above average" and "below average" counts on the basis of crowing counts. The roadside count data for these same routes were also compiled for comparison. Close correlation between the two techniques was found, as the "above average" routes showed 140 and 141 per cent of average and "below average" routes 61 and 59 per cent of average for the crowing count and roadside count respectively. The crowing counts were run once, while the roadside figures are an average of three runs. It is thus apparent that

crowing counts and roadside counts will yield comparable results where 75 or more roadside counts are included in the sample. That is, they will yield comparable results in showing relative abundance in different places. This does not prove that results will be comparable in showing population trends from one year to the next.

EFFECT OF VARIABLE FACTORS

Probably the principal reason for the apparent accuracy of the crowing count lies in the fact that few errors are introduced through variable factors. Temperature, wind velocity, nebulosity, precipitation, fog, and amount of dew have been recorded with all counts. Relative humidity has also been recorded with many counts. Nebulosity, relative humidity, fog, and amount of dew have to date shown no measurable effect upon crowing counts. Extremes of temperature may have some effect upon crowing but this is very seldom a factor. Crowing may remain near normal in a light shower but counts cannot be taken during rain or snow. Wind presents the greatest problem but counts taken when the wind velocity is below 8 miles per hour will not be affected. Counts should not be taken during thunder storms as the cocks call in response to a loud noise.

If the above findings are correct it is obvious that weather will inject far fewer variable factors into crowing counts than into censusing techniques which are based on seeing rather than, hearing, birds. Randall and Bennett (1939:435) state, "They [roadside censuses] should be made on clear fall days having normal dew-fall. Rainy, foggy, cloudy, and dewless mornings are not satisfactory times." Hicks *et al.* (1941:8) and all who have done any work with the roadside census have recognized the effect of dew. The effect of nebulosity upon roadside counts still appears to be a point of conjecture but indications are that previous rain, wind, dew and probably temperature and cloudiness affect the number of birds which will be seen on a roadside count.

TABLE 4.—COMPARISONS OF SIZE OF SAMPLE AND CORRELATION BETWEEN CROWING COUNT AND ROADSIDE COUNT

	Above Average		Below Average		Total	
	Crowing Count	Roadside Count	Crowing Count	Roadside Count	Crowing Count	Roadside Count
No. of routes	25	25	26	26	51	51
Count per 2 minutes or mile	59.48	.82	25.85	.34	42.33	.58
% of average	*140*	*141*	*61*	*59*	—	—
Calls heard per birds seen	72.5	—	76.2	—	73.1	—

OTHER VARIABLES

Any census method based on birds seen will be affected by cover conditions;

whether annual vegetation is rank, sparse, early or late; type of farm crops planted; cutting date of grain, hay, and other farm crops; extent and date of roadside mowing; and any other factor which affects visibility. None of these factors is believed to affect the number of cock calls which will be heard.

A factor which could affect audibility counts is the ability of air to conduct sound under varying atmospheric conditions. Information thus far obtained indicates that little or no trouble may be expected from this source.

Tyndall (1901) states, "Rain has no sensible power to obstruct sound. Hail has no sensible power to obstruct sound. Snow has no sensible power to obstruct sound. Fog has no sensible power to obstruct sound." The factor which, according to Tyndall, does affect sound transmission through air is invisible "acoustic clouds." Apparently these have the least effect near sunrise of each day, at which time crowing counts are taken.

The fact that a low coefficient of variation occurs when crowing counts are taken from the same locations at various times, also bears out the belief that changing ability of air to conduct sound is not an imporatnt variable factor.

The distribution of pheasants throughout their range is also a factor to be considered. During the spring and early summer, when crowing counts are taken, pheasants are probably spread more homogeneously throughout their range than at any other time of year. This increases the accuracy of a small sample. In the Dakotas, where pheasants will move up to 10 miles or more to winter cover, it would require a very large sample to provide a reliable index to the population between late fall and early spring.

COST OF CONDUCTING A CROWING COUNT

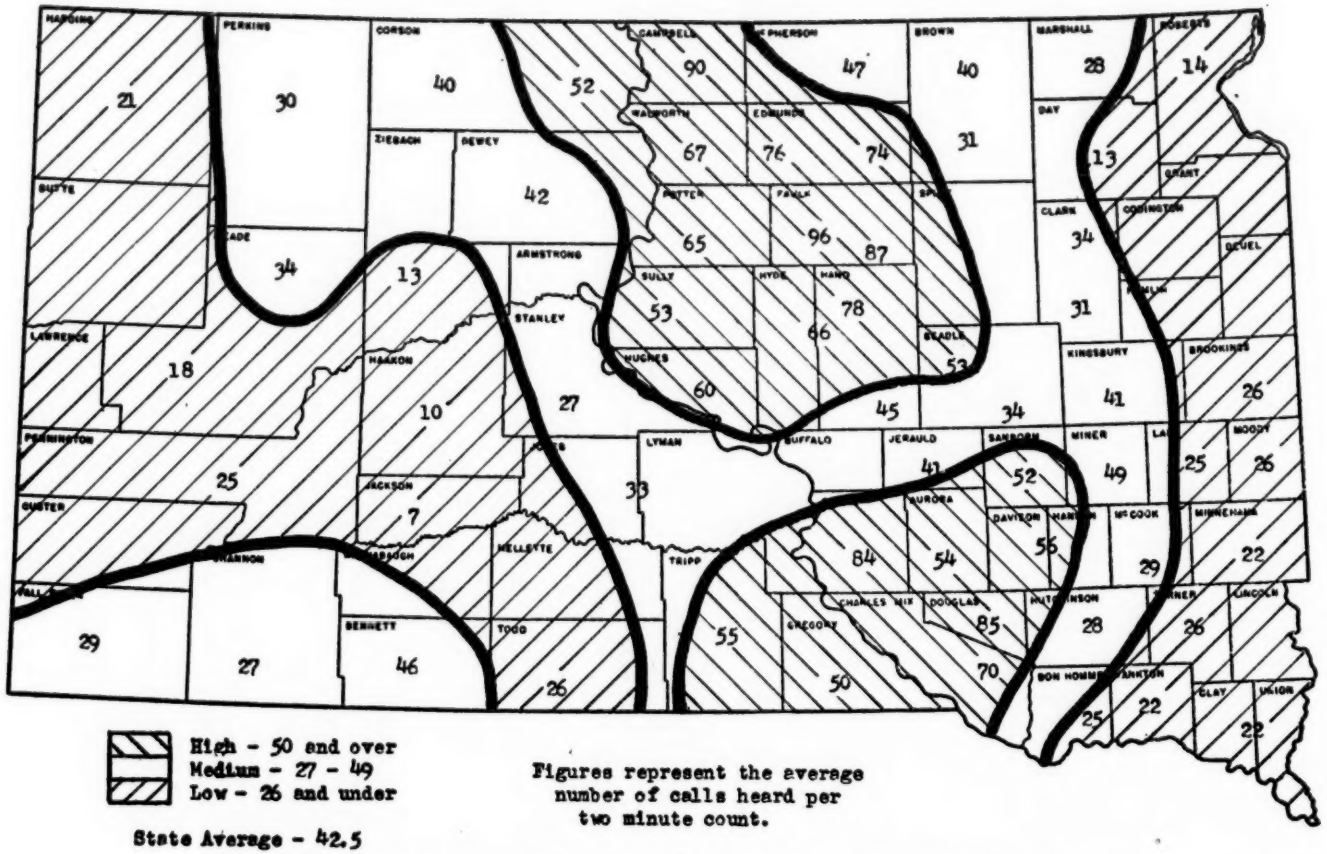
With the exception of the rural mail carrier survey, the crowing count is the least expensive of pheasant censusing methods. In South Dakota each roadside census route was run three times. More reliable results were obtained by making one crowing count on each route. The time and expense involved in making a roadside or crowing count is about the same. Therefore, the crowing count produces more accurate data than the roadside count at one-third the cost.

APPLICATION OF THE CROWING COUNT

The crowing count is unique in that it can be applied equally well to small areas of intensive study or to an entire state; and to a low, as well as to a high population. It is not limited solely to censusing. It has already been successfully used to show extent and direction of pheasant movements and to determine extent of mortality through storms.

In South Dakota the crowing count is being used intensively in areas where habitat improvement work is being done These counts compared with counts taken on control areas and on regular routes in the vicinity are expected to show the effectiveness of our development program.

Crowing counts are, or course, also being used extensively in South Dakota to determine the distribution and trend of our pheasant population. In 1947,



High - 50 and over
Medium - 27 - 49
Low - 26 and under

State Average - 42.5

Figures represent the average number of calls heard per two minute count.

FIG. 3.—South Dakota pheasant population, Spring, 1947, as determined by crowing counts.

(the second year of crowing counts in South Dakota) 61 routes were run in 53 counties. It was learned that the spring population had decreased 19 per cent and that the island of highest population had shrunk in size. Thus it was possible in June to notify the Director and the Commission of the Game Department that a reduction in the fall pheasant population was a strong probability.

Figure 3 shows that the crowing couunt index figures group nicely and it is not difficult to map the areas of high, medium, and low population. The same general population pattern is shown by the roadside count and the rural mail carrier survey. However, even though 3 runs are made on each roadside route and the mail carriers cover 132,071 miles these data do not show the continuity of pattern that is found in the crowing count data.

In 1946 the once solid strip of maximum pheasant population extending through South Dakota was found to be constricted in the center. The 1947 counts showed that this constriction had continued and a belt of medium population had cut the high area in half.

The crowing count is probably most useful in censusing low pheasant population. Bach (1944) states, "Evidence points to the fact (here in North Dakota) that our method of roadside censusing becomes rather unreliable when used on populations running about 30 birds to the section or less." The writer believes that even in a population of 50 birds per section a very large roadside count sample would be required to produce significant results.

It will be noticed in Table 2 that the coefficient of variation remains small regardless of the average number of calls per 2 minute period. In southeastern Minnesota the 1945 pheasant population was so low that 5 or 10 roadside counts might be required to see one pheasant. However, an average of 2.3 calls were heard per 2 minute count and for 5 runs the standard deviation was 0.22 and the coefficient of variation 9.6 per cent.

The crowing count has been successfully used to determine the effect of hail storms upon adult pheasants. Kimball (1945) states, "It appears therefore that the only explanation for the 78.5 per cent decrease in crowing following the storm is that this percentage of cock pheasants was either killed by the hail or injured to the extent that breeding was discontinued." This study was possible because a crowing count had been run across the area which was later stricken by an extremely severe hail storm. The route was re-run four days following the storm and a decrease of 78 per cent was noted within the area of severe hail, while counts on the portion of the route which received heavy rain but no hail remained the same. Sixteen days following the storm a third count indicated movement of cocks into the hail area to fill the void. This was indicated by an increasing count within the hail area and a proportionately reduced count surrounding the area.

Of course routes cannot be laid out in anticipation of catastrophies other than those made by man. However, storms, fires, and other phenomena which affect adult pheasant populations will occasionally cross the path of a crowing count route, making study of the effects possible.

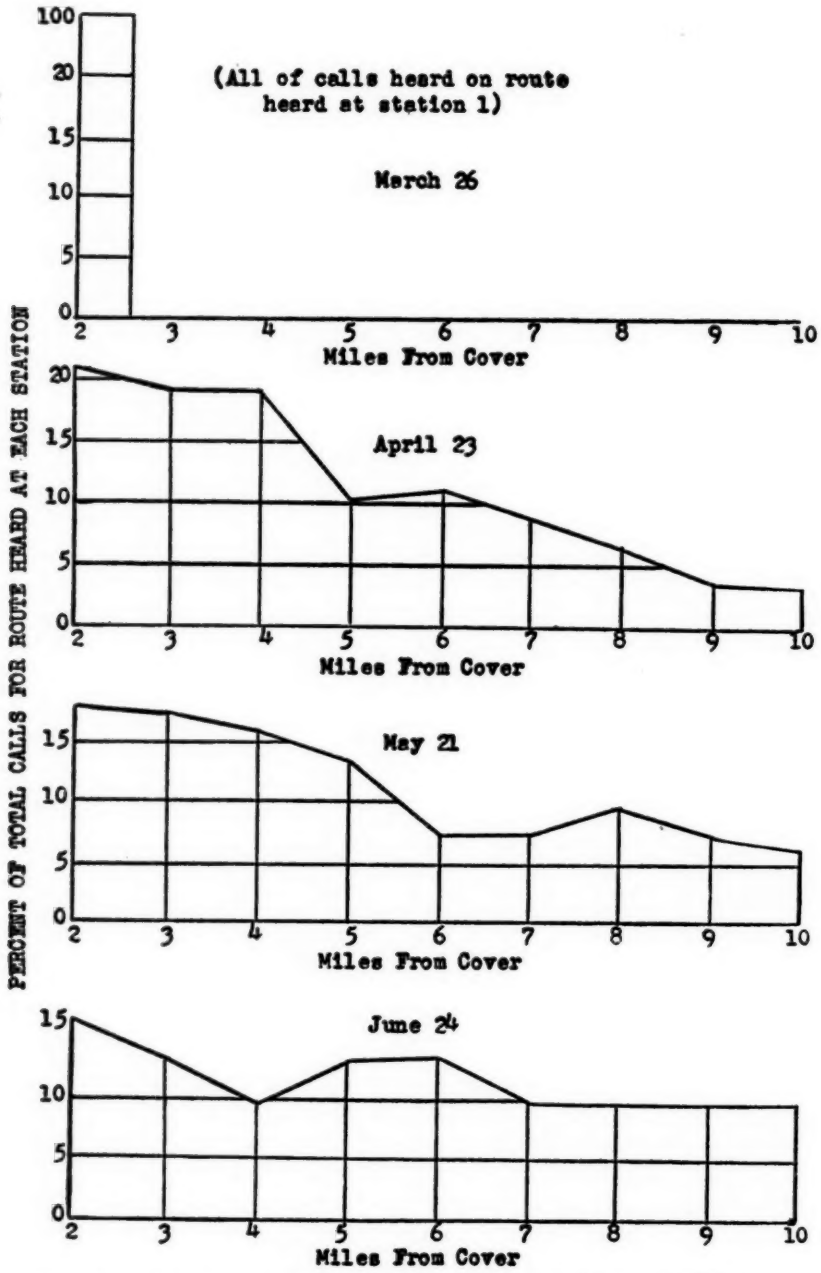

(All of calls heard on route heard at station 1)
March 26
April 23
May 21
June 24
PERCENT OF TOTAL CALLS FOR ROUTE HEARD AT EACH STATION
Miles From Cover

FIG. 4.—Use of crowing counts to demonstrate spring dispersal from wintering area.

Crowing counts have also been successfully used in ascertaining seasonal movements of pheasants. In the spring of 1947 Reuel Janson ran a route extending from 2 to 10 miles west from a concentration of pheasants in the Missouri River Valley near Mobridge, South Dakota. The river valley provided the only winter cover in the vicinity of the route. On the first run (March 26) 24 calls per two minutes were recorded on the count nearest the river and no calls were heard on any of the stops farther west. Successive runs of the same route showed the progressive movement away from winter concentration during the spring.

Figure 4 shows that pheasants in South Dakota move at least 10 miles from winter cover to breeding range. In all probability, a return movement is made in the fall.

This information has been extremely useful in determining the value of winter habitat which will be destroyed by Missouri River basin development, and in determining the need for cover development to replace that which will be lost. Additional studies of this nature will be conducted in South Dakota, and Bach has made similar studies with like results in North Dakota.

CONVERTING THE CROWING COUNT POPULATION INDEX INTO A TRUE CENSUS

There appear to be two general methods by which the crowing count index method can be converted into a true census. This could be accomplished by conducting crowing counts in areas of known population. To date, however, we have not been able to ascertain with accuracy the spring pheasant population on any area in South Dakota.

A crowing count census can also be developed by learning the average crowing frequency of cocks and the average distance at which they can be heard. Determination of crowing frequency is not difficult. Eleven cocks were observed crowing in South Dakota in 1946. Eighty-one calls were recorded for an average frequency of 2 minutes, 54 seconds. Very similar results were obtained in observing crowing frequency of lower populations in Minnesota and Nebraska. Further data on crowing frequency can be easily obtained when needed.

Crowing frequency and/or the percentage of cocks which crow may or may not be in direct proportion to the population. At least two factors could be operating against a direct proportion. Crowing of each cock may be stimulated by crowing of other cocks in the vicinity. This would mean that a crowing count of 50 would represent something less than twice the population where a count of 25 was recorded. On the other hand, there may be such a thing as "whipped out" cocks which do not crow at all. A few observations indicate that such a condition may exist. An increase in population would then produce something less than a proportional increase in crowing.

The average distance at which cock calls can be heard is less easily obtained. This distance represents the radius of the circle within which calls are being heard. Therefore, a small error in determining this radius will result in a much greater error in the area of the circle of audibility. However, the distance at which cock calls can be heard may be quite definite, thus reducing the possibility of great error. Zahn (1900) states, "The loudness of sound varies

inversely as the square of the distance of the sonorous body from the ear (Mersenne's law). At this rate, one standing twenty feet away from the [tuning] fork just used, the sound would be only ¼ as loud as to one standing but 10 feet away." Thus it seems logical to assume that the maximum range of audibility will not deviate too greatly when loudness varies with the square of the distance, rather than with the distance, at which it is heard.

W. E. Banko, with the South Dakota Department of Game, Fish and Parks, has made a good beginning in determining the distance at which cock calls can be heard. However, his studies cover only one spring period and are far from conclusive. Indications are that normal calls can be heard roughly nine-tenths of a mile. However, many factors remain to be worked out, and no attempt will be made to use the crowing count as a true census until greater accuracy is obtained. Banko has made one suggestion in particular which appears to merit further study. This is to measure in decibels, by use of instruments, the loudness of cock calls at known distances. Then, through application of Mersenne's law, determine the theoretical distance at which calls can be heard. It is realized that complications will arise as decibel intensity for sounds of various tones produce somewhat different effects of loudness.

FUTURE POSSIBILITIES OF AUDIO CENSUSING

Exploration of the field of audio censusing of game birds has just begun. South Dakota and other states are developing an index to prairie chicken populations through booming counts. We have already obtained information on distribution of both sharp-tailed and pinnated grouse through courtship ground records taken while running crowing count routes plus additional routes established for this purpose. Rudolf Bennitt has been obtaining data on Missouri quail population for several years through whistling counts. Audio censusing of many species which have mating calls appears to be feasible. Among these, in addition to pheasants, pinnated grouse, sharp-tailed grouse, and quail, are ruffed grouse, woodcock, Wilson's snipe, mourning doves, and possibly many others. Mourning doves have been censused by "cooing counts." McClure (1939) states, "Since there is a direct relationship between the number of mourning doves present in an area and the number cooing, it is possible to determine populations by counting the cooing birds." Nice (1943) in recording two instances of morning singing by song sparrows states, "He sang rather steadily for the first 2 hours at an average rate of 4.8 songs a minute."

The fact that pheasants call in response to loud noises may eventually find a place in censusing. Censusing by detonations may be useful where populations are extremely low or at seasons of the year when spontaneous crowing is low. McClure (1944) states, "In all probability the use of one minute counts at each stop is as effective, if not more effective, than the use of the bomb as a method of estimating populations for the pre-breeding and breeding months. For the remaining eight months of the year the detonation method continues to be effective."

It also seems that an audio census of

certain mammals would be feasible. A census, or at least a population index, of thirteen-lined ground squirrel populations, for example, could probably be worked out rather easily.

The use of electric audio equipment may be an eventual refinement of audio censusing. This equipment could possibly eliminate human error, and, through the use of ban pass filters, eliminate most interference noises. Bach has already experimented with such equipment. Wire recorders might also be used in connection with such equipment. By so doing all counts could be heard by the same man, thus eliminating variation due to individual ability.

Another relatively unexplored field for use of crowing counts is to apply them to soil types and general geographic or geologic areas. The small amount of data available indicates that a crowing count population index worked up on soil types would yield gratifying results. In Figure 3 it will be noticed that Beadle County shows a count of 53 in the northwest and 34 in the south. Later study revealed that a sandy soil prevails in northeastern Beadle County and that pheasants have always been more abundant here than in the heavier soils farther south in the county. In Nebraska one run consistently showed three low counts in the center of the route. A change in soil type was the only apparent reason for the reduced count. In northeastern South Dakota a material increase in the number of calls per 2 minutes is recorded where the route leaves the Coteau des Prairie and drops into the James River Basin to the west.

A further possible use of the crowing count is suggested by Smith (1947). He found that the time required for laying and incubating eggs closely approximated the period between peak crowing and peak hatching. He states, "Further studies would be required to determine whether or not this relationship is one of coincidence. If the conclusion is valid, pertinent information, exclusive of population trends, could be derived from crowing count, particularly in an area such as Utah where the date of the hatching peak as related to farm practices assumes great importance."

The crowing count in its present form is presented as a dependable index to pheasant cock populations in the spring. This alone has been quite dependable in predicting fall populations. With knowledge of the sex ratio it becomes an index to the total adult population and with late summer data on reproductive success it becomes an index to fall populations. It is the author's opinion that audio censusing will be one more useful tool in the most important study of all—the study of wildlife populations.

SUMMARY

Data on crowing counts have been collected over a period of 4 years in three states and include 304 mornings' work, 5,989 two minute counts, and 162,940 recorded cock calls.

Recommended procedure for conducting a crowing count census is given and discussed.

Variation in human ability to hear cock calls appears to be low—showing a coefficient of variation of 1.5 per cent.

The maximum average variation in crowing intensity between −40 and +50 minutes sunrise appears to be ±7.5 per cent of average.

Spring dates between which a crow-

ing count census should be taken may vary somewhat with the season and the geographic location. During the six week censusing period of 1947 the maximum error due to seasonal variation in crowing was ±3 per cent of average.

Through repeated runs on the same census routes the coefficient of variation for crowing counts averaged 8.4 per cent compared to 40.0 per cent for roadside counts.

The sample obtained by crowing counts is approximately 75 times that obtained by roadside counts.

Crowing counts and roadside counts in South Dakota yielded comparable results in showing population distribution where 75 or more roadside counts were included in the sample.

Weather factors, with the exception of wind above 8 m.p.h. and heavy precipitation apparently seldom affect crowing counts. Most variable factors such as weather, condition of cover and crops, etc., appear to affect audio censusing much less than censusing by eye.

As conducted in South Dakota, the crowing count produces more accurate results than the roadside census and does it at one-third the cost.

Crowing counts can be applied equally well to small or large areas and to low or high populations. They are especially valuable in censusing low pheasant populations.

Crowing counts are being used to determine population trends, distribution, spring storm mortality and movement. By their use pheasants have been shown to make seasonal movements of at least 10 miles.

Audio censusing is an undeveloped field which through refinement may provide accurate population data on many species.

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SALT (SODIUM CHLORIDE) REQUIREMENTS OF GROWING BOBWHITE QUAIL

Ralph B. Nestler

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Sodium and chlorine are dietary essentials. They help maintain the necessary osmotic pressure and surface tension of the various fluids of the body, and so aid in absorption, excretion, and secretion. They are also concerned in the regulation of the hydrogen ion concentration of the blood and tissues. For example, the acidity of the gastric juice of the proventriculus, which is necessary for the activity of the proteolytic enzyme pepsin, is due to hydrochloric acid derived chiefly from sodium chloride in the blood. The normal pH of blood is partially maintained by the carbonates and phosphates of sodium. Sodium is needed by all plant-eating animals for the elimination of the excess of potassium contained in the feed. In the case of growing chickens fed mainly on ingredients of cereal origin, the addition of a small proportion of common salt (sodium chloride) to the diet leads to accelerated growth (Branion, 1938, and Ewing, 1947).

According to Halpin and associates (1936), 0.5 per cent of salt in the feed will meet the requirements of growing domestic chicks. In fact, they found that when poultry rations contain the usual amounts of meat scraps, fish meal, and dried milk, even as much as 0.5 per cent additional salt can be excessive. Nevertheless, studies by Quigley and Waite (1932) show that chicks have a high tolerance for sodium chloride, a finding which is contrary to general belief. Therefore, for best all around results, 0.5 per cent of additional salt in the feed is now generally advocated for all poultry.

In several previous articles, the author has pointed out the value of salt in the control of picking among bobwhite quail in captivity, and its high tolerance by this gamebird (Nestler, 1940, 1943; Nestler, Coburn, and Titus, 1945). However, according to the literature, apparently no studies have been made on the salt requirement of quail. Therefore, in 1947 two experiments with bobwhite quail chicks were conducted at the Patuxent Research Refuge, Laurel, Maryland, to obtain information on this point.

Procedure

In Experiment 1 duplicate pens of 16 birds each were used for each of the seven diets compared; in Experiment 2 a single pen of 33 chicks was placed on each diet. Within twenty-four hours after being hatched the chicks were fed the experimental diets. No grit was provided throughout the studies. The feed was kept before the birds at all times.

The following basal feed mixture was used for all the diets:

	Per cent
Ground yellow corn	*33.5*
Soybean oil meal	*51.0*
Dried skim-milk	*10.0*
Flavin concentrate	*2.0*
Ground limestone	*0.6*
Tricalcium phosphate	*1.4*
Vitamin A and D feeding oil, fortified	*0.5*

After supplementation with salt the

formula was made up to 100 per cent by the addition of more ground yellow corn. For Experiment 2, manganous sulphate was added to the basal feed mixture in sufficient quantity to supply 100 parts of manganese per million parts of the diet. The diets differed as follows: 1—no salt added; 2—0.25 per cent NaCl; 3—0.50 per cent NaCl; 4—0.75 per cent NaCl; 5—1.00 per cent NaCl; 6—0.25 per cent Na_2SO_4; and 7—0.50 per cent KCl.

The birds were weighed when placed on the experiments and every two weeks thereafter until they were ten weeks old. A record was kept on the consumption and waste of feed.

RESULTS

The combined results of the two experiments at the end of ten weeks, are summarized in Table 1.

TABLE 1.—EFFECT OF SODIUM AND CHLORINE ON GROWING QUAIL AT THE END OF TEN WEEKS

Supplement	Average Bird-weight (grams)	Survival (%)	Feed Consumed per Bird per Day (grams)
No salt	126	*64*	7.2
¼% NaCl	146	*58*	7.7
¼% Na_2SO_4	136	*66*	7.4
½% KCl	133	*59*	7.4
½% NaCl	139	*78*	7.8
¾% NaCl	144	*80*	8.2
1% NaCl	143	*76*	8.4

Survival. The highest survival occurred on 0.75 per cent NaCl, but the difference between that and the survival on 0.50 per cent and 1.00 per cent NaCl is inconsequential. The other four diets showed greater mortality. None of the differences, however, is statistically significant.

Bird-weights. The following differences in bird-weights are highly significant (odds of 99 to 1): between results on each of the four sodium chloride levels and the diet containing no salt; and between results on either 0.25, 0.75 or 1.00 per cent of sodium chloride and 0.50 per cent potassium chloride. The differences between the results on 0.25 per cent sodium sulphate and the diet containing no salt; and between the results on 0.25 and 0.75 per cent sodium chloride and 0.25 per cent sodium sulphate, are also significant but only according to odds of 19:1. None of the other differences is important.

Feed Consumption. The consumption of feed increased directly as the addition of sodium chloride to the diet was raised from zero to 1.00 per cent.

DISCUSSION

From the standpoint of growth of birds the results on the sodium sulphate and potassium chloride were both nearly as good as those on the 0.50 per cent level of sodium chloride. Then, too, in order to make the data more difficult for interpretation, the results obtained from sodium sulphate and potassium chloride in Experiment 2 were exactly the reverse of those in Experiment 1 (Table 2). In the latter case, weights on Na_2SO_4 at the end of

TABLE 2.—SURVIVAL AND WEIGHTS OF QUAIL AT END OF TEN WEEKS ON LEVELS OF Na_2SO_4, KCl, AND NaCl

Supplement	Average Bird-weight (grams)		Survival (%)	
	Exp. 1	Exp. 2	Exp. 1	Exp. 2
¼% Na_2SO_4	150	111	*87*	*45*
½% KCl	132	133	*70*	*48*
½% NaCl	146	130	*84*	*74*

ten weeks were equally as good as those on 0.5 per cent NaCl, whereas the weights on the KCl were significantly lower. The author has no explanation for this disparity between the two studies.

SUMMARY

In the two experiments involving 452 bobwhite quail chicks, seven diets containing the following salt supplements, were compared: No additional salt; 0.25 per cent NaCl; 0.50 per cent NaCl; 0.75 per cent NaCl; 1.00 per cent NaCl; 0.25 per cent Na_2SO_4; and 0.50 per cent KCl. All four diets containing sodium chloride gave about equal results in bird-growth, and produced better weights than the diet containing no additional salt. Survival was high on the 0.50, 0.75 and 1.00 per cent levels, especially the 0.75 per cent level. Feed consumption increased directly as the salt level of the diet was raised.

The results on the Na_2SO_4 and KCl while better than those on no saline supplementation, and somewhat inferior to those on NaCl, nevertheless are inconclusive because of inconsistency.

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SUPPLEMENTS TO YELLOW CORN FOR WINTER-MAINTENANCE AND SUBSEQUENT REPRODUCTION OF QUAIL

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Yellow corn is a very important food for northern bobwhite quail in winter. Recent studies have emphasized this fact but the importance of corn as a winter food has been recognized for years. In 1936 Errington stated:

"Yellow corn (*Zea mays*) is one of these nearly complete sustentative foods. Wild populations of both pheasants and quail have been known to subsist for entire winters almost exclusively on corn, examinations of droppings revealing but the barest traces of other food residues. Birds of both species have been confined experimentally in outdoor pens and given

access to no food except corn from January to April with no average loss of weight. It is conceivable that under exceptionally extreme circumstances—4 or 5 feet of snow persisting all winter in a uniform layer—the birds may suffer from a certain amount of unbalance in diet, but they can endure some unbalance and still survive. There are other foods which field and experimental evidence prove to be of outstanding value as staples for quail and pheasants, but none for which the case is so clear as that of corn."

Nestler (1946) in his studies on the vitamin A requirements of quail, found that gamebirds can survive and gain weight on yellow corn, supplemented only by additional vitamin A in cottonseed oil, or by two per cent of alfalfa leaf meal. Nevertheless, they may die within a few weeks on diets of carotene-lacking grains, such as white corn, wheat or rye, soybeans, minerals, and other wholesome foodstuffs high in food value but deficient in vitamin A. It was concluded that during the winter especially vitamin A apparently stands on a par with carbohydrates as a factor that decides the fate of quail. *Yellow* corn is the *only* cereal that contains an appreciable quantity of the provitamin A.

For maintenance in winter the protein requirements of quail is low (Nestler, Bailey, Llewellyn, and Rensburger, 1944)). Satisfactory body-weights and subsequent reproduction were obtained on only 11 to 13 per cent crude protein, levels slightly higher than that furnished by corn alone.

The present experiment (1947) was planned to determine what ingredients should be added to yellow corn, not only to keep quail alive and in good flesh throughout the winter, but also to provide them with the necessary dietary factors and stamina for good health and optimum reproduction during the subsequent breeding season.

PROCEDURE

All the birds used on the experiment were blood-tested for ulcerative enteritis, and only those that reacted negatively were used. Fifteen were distributed into each of eighteen pens, the distribution being made on the basis of body-weight and dietary history. Nine diets were fed to duplicate pens. No grit was supplied. The diets were as follows:

Diet 1. Yellow corn (ground in hammer mill with ¼ inch screen).

Diet 2. Diet 1 modified by the addition of 0.5 per cent cottonseed oil.

Diet 3. Diet 1 modified by the addition of 0.5 per cent cottonseed oil containing vitamin A acetate (3000 I.U. per gram of solution).

Diet 4. Diet 1 modified by the addition of 0.5 per cent cottonseed oil containing vitamins A and D from fish liver (3000 I.U. vitamin A per gram; 425 I.U. vitamin D per gram of solution).

Diet 5. Diet 4 modified by one per cent salt mixture (100 pounds iodized NaCl plus 1.7 pounds of anhydrous manganous sulphate) replacing equal parts of corn.

Diet 6. Diet 5 modified by 1.2 per cent of steamed bonemeal replacing equal parts of corn

Diet 7. Diet 6 modified by 5.0 per cent alfalfa leaf meal replacing equal parts of corn.

Diet 8. Diet 7 modified by 8.0 per cent soybean oil meal replacing equal parts of corn.

Diet 9. Diet 7 modified by 4.8 per cent liver meal replacing equal parts of corn.

The experiment was run for three months, the birds being weighed every two weeks, and their feed consumption recorded. At the beginning of the subsequent breeding season eight pairs of quail from each maintenance diet were evenly distributed on the production diets, so that changes in the latter diets would have no significant effect on the results obtained as a consequence of the winter's dietary regimen. The results were analyzed statistically, and are summarized in Tables 1 and 2.

RESULTS

During Winter: Survival was good on all the diets. Most of the deaths were the result of mechanical injury.

The addition of the salt mixture caused a marked increase in feed consumption.

TABLE 1.—EFFECT OF MAINTENANCE DIETS ON SURVIVAL, WEIGHT, AND FEED CONSUMPTION OF QUAIL

Diet No.	Diet Main Ingredients Additional to Corn	Survival %	Feed Eaten per Bird per Day (gm.)	Weight at 12 Weeks (gm.)	Gain or Loss (grams) from Initial Weight by Weeks					
					2	4	6	8	10	12
1	Corn only	*97*	14.1	145	−2	−4	−7	−17	−24	−28
2	Cottonseed oil	*100*	14.2	146	−1	−3	−6	−15	−21	−28
3	Vitamin A	*87*	14.6	141	0	−4	−8	−19	−27	−33
4	Vitamin D	*100*	14.7	152	−1	−3	−3	−13	−16	−22
5	Salt mixture	*100*	15.3	161	4	−1	0	− 6	− 8	−11
6	Bonemeal	*100*	15.2	169	2	0	−1	− 6	− 6	− 7
7	Alfalfa	*97*	15.9	172	6	3	3	− 1	− 3	− 3
8	Soybean meal	*100*	15.2	171	8	3	3	0	− 1	0
9	Liver meal	*93*	15.2	177	4	1	1	− 1	− 3	− 1

TABLE 2.—EFFECT OF MAINTENANCE DIETS IN WINTER ON SUBSEQUENT REPRODUCTION AND HEALTH OF QUAIL

Diet No.	Diet Main Ingredients Additional to Corn	Survival %	Gain or Loss in Weight (gms.)	Precocity 1st 2 weeks in May		Persistence Last 2 weeks of August		Total Eggs Laid	Fertility (%)	Hatchability (%)
				% birds	No. eggs	% birds	No. eggs			
1	Corn only	*88*	4.6	*6*	3	*14*	15	58	*92*	*71*
2	Cottonseed oil	*88*	3.6	*25*	11	*14*	12	55	*95*	*67*
3	Vitamin A	*94*	5.8	*13*	3	*7*	2	49	*81*	*55*
4	Vitamin D	*88*	8.5	*19*	13	*22*	14	63	*71*	*61*
5	Salt mixture	*81*	−3.2	*0*	0	*15*	6	43	*85*	*64*
6	Bonemeal	*93*	−2.4	*13*	13	*14*	22	62	*72*	*53*
7	Alfalfa	*88*	−5.3	*6*	2	*7*	11	64	*93*	*60*
8	Soybean meal	*94*	−7.7	*31*	17	*27*	16	66	*93*	*54*
9	Liver meal	*80*	−9.3	*19*	5	*17*	7	47	*82*	*65*

The birds on the last five diets maintained their weights significantly better than those of the first four (odds of more than 99:1). Likewise the quail on the last three diets containing alfalfa were significantly heavier throughout much of the experiment, than those on Diet 4, and also Diet 5, except during the least two weeks. As the birds approached

breeding season the addition of the bonemeal to Diet 5 helped the birds to hold their weight better than those on Diet 4.

The lowest weights at the close of the experiment were among the quail on Diet 3, corn supplemented with vitamin A acetate. The possibility that the birds suffered from hyper-vitaminosis was indicated by the abnormal rarefaction and fragility of the bones as well as the rapid loss in weight. (See Rosenberg, 1945.) Other studies by the author (unpublished data) have revealed a much higher efficiency of utilization by quail of this form of vitamin A based on storage in the liver, than either vitamin A alcohol or the natural vitamin A ester.

During Subsequent Breeding Season: The survival, precocity, and laying persistence of the birds, and the number, fertility, and hatchability of eggs, was just as high among the quail that had wintered on either yellow corn as the sole article of diet or on corn plus only oil and vitamins A and D, as it was among the quail that had used Diets 5–9.

Regarding maintenance of weight, the results were exactly the reverse of those obtained during the winter, the birds that had been on the first four diets holding their weights significantly better than those on the last five (odds of more than 99:1). Possibly the differential was mostly water rather than fat, taken on and held during the winter by the birds on the salty diets, but lost during the summer. (See Ewing, 1947.)

SUMMARY

In a study at the Patuxent Research Refuge with 270 bobwhite quail, *yellow* corn alone as a maintenance diet helped the birds to survive the winter and reproduce as successfully during the subsequent breeding period, as did corn supplemented progressively with cottonseed oil, vitamin A, vitamin D, salt, bonemeal, alfalfa leaf meal, soybean oil meal as a plant protein, and liver meal as an animal protein. The addition of salt to the corn helped the birds to maintain their weight better through the winter, than when either corn alone or corn plus oil and fat-soluble vitamins were fed. Also alfalfa leaf meal as a supplement tended to improve maintenance of weight. Nevertheless, whatever vantage was gained in weight-maintenance during the winter by the quail on diets containing salt and alfalfa, was lost during the subsequent breeding season. At that time those birds that had been on either corn alone or corn plus oil and fat-soluble vitamins, held their weights better than the others. The presence of bonemeal in the maintenance diet seemed to be advantageous only at the time just prior to the start of the reproduction period. Animal protein showed no advantage over plant protein, and neither improved the diet containing alfalfa leaf meal.

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AN IRRUPTION OF ELK IN RIDING MOUNTAIN NATIONAL PARK, MANITOBA

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Introduction

Riding Mountain National Park, containing an area of 1,148 square miles, is situated in southwestern Manitoba, approximately 140 airline miles northwest of Winnipeg. Its main axis, with a length of 67 miles, lies east and west. Its maximum width is 26 miles.

The park occupies a plateau with an average elevation of about 2,000 feet. The northern and eastern slopes rise abruptly 1,000 feet from the Manitoba prairies; the southern slope is more gradual. The plateau dips gently to the west, where, 15 miles from the provincial boundary, it imperceptibly merges with the general level of the Saskatchewan plain.

The greater part of the park, including the northern and eastern regions, supports a northern boreal association. This area is heavily forested with mixed stands of white spruce (*Picea glauca*), jackpine (*Pinus Banksiana*) and aspen (*Populus tremuloides*). Pure stands of these dominant trees also occur. Black spruce (*Picea mariana*) and tamarack (*Larix lariciana*) are widely distributed in poorly drained areas.

The western and southern areas of the park support an aspen parkland association where the characteristic trees are aspen and balsam poplar (*Populus balsamifera*). In this area are numerous prairies which appear to be more less permanent in nature. One of the notable features of the park woods is the dense undergrowth of shrubs. Alders (*Alnus* sp.), hazelnut (*Corylus americana*), dwarf birch (*Betula glandulosa*), and saskatoon (*Amelanchier alnifolia*) form thickets which impede observation and travel.

In 1929, when the park was established (having been formerly a Dominion Forest Reserve), there was a nucleus herd of native Manitoba elk (*Cervus canadensis manitobensis*) on the plateau. The early history of this Riding Mountain herd has been recorded by Green (1933), who gathered much pertinent information on the status of the herd at the time of the initial settlement of the surrounding area and when the plateau was a forest reserve.

The growth of the herd is indicated by past estimates of the elk population, made by park officials: 1914—500, 1925—2,000, 1933—3,500, 1941—5,000 to 7,000, 1946—12,000. There has not been a steady population growth. In the winter of 1935–36 there were severe losses in population, due to severe winter kills. Coupled with increase in population there has been an evident increase in browse utilization.

The winter of 1946–47 was a severe one in most of central Canada. In the Riding Mountain area exceptionally deep snow and low temperatures prevailed during the early winter. During late winter there were several thaws, followed by cold snaps, which caused thick crusts to form on the snow. These

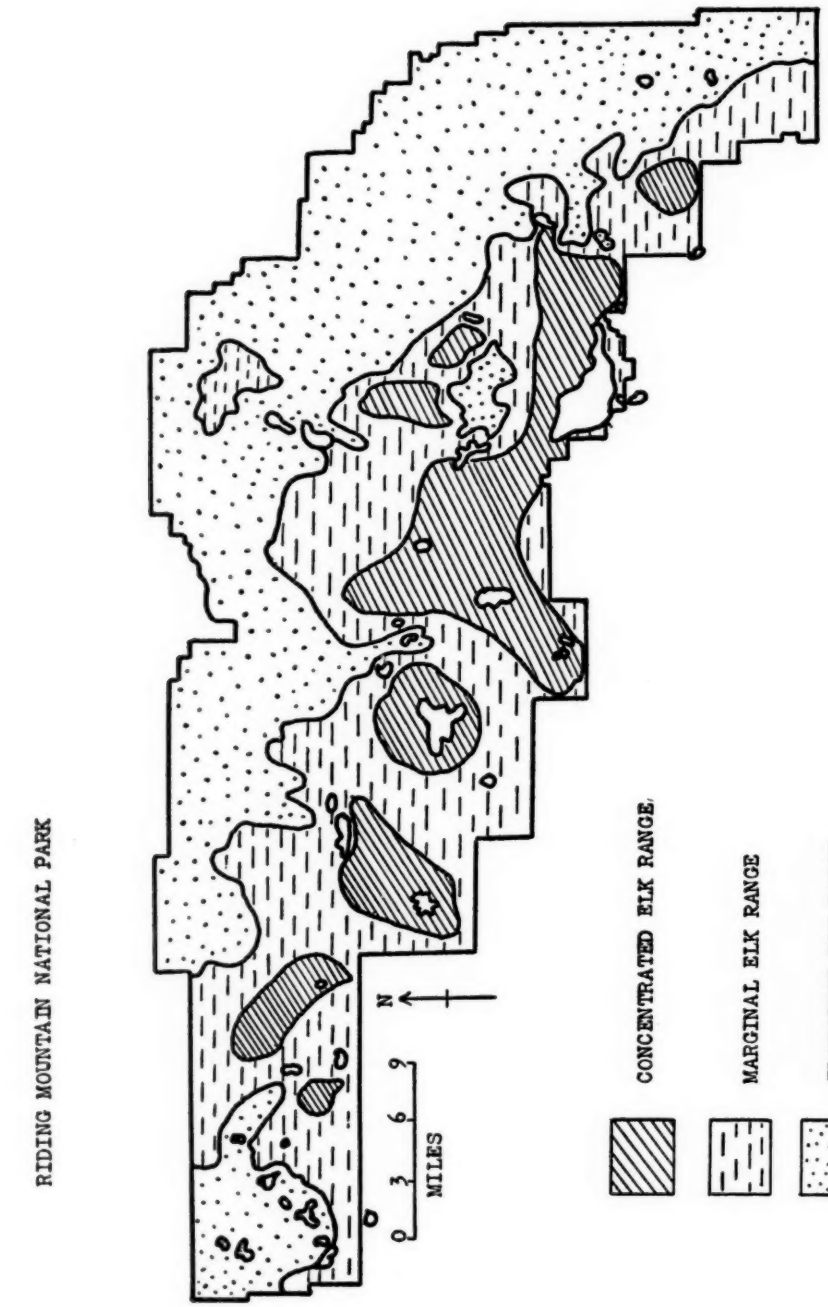

FIG. 1.—Map of Riding Mountain National Park, Manitoba, indicating the Elk range.

conditions brought about increased hardship for the ungulate mammals.

This paper is based on investigations carried out in the park during the periods January 16 to 31, and May 10 to June 13, 1947.

ELK RANGE

Elk may be encountered anywhere in the park. They are most abundant, however, on the extensive areas of grassland and wet meadows; they also inhabit the second growth aspen stands; they are rare or absent in the mature stands of conifers or mixed hardwoods and conifers.

The approximate present elk range as known from wardens' reports and personal observation has been indicated in Figure 1, which is based on the forestry cover-type map of the park. The total range has been divided into two parts. The first consists of the main prairies, parklands and open aspen stands, which harbor the principal concentrations of elk. At present population levels, this part of the range is overstocked and shows heavy browse utilization. The second division comprises marginal habitats, consisting of moderately open aspen stands. The third division, which is covered by coniferous stands as well as by mixed stands of sufficient density to yield 30 cords or more to the acre, is regarded as outside the range, as it is believed to be used by transient animals only. The total areas of these divisions within the park are as follows: concentrated elk range, 180 square miles; marginal range, 400 square miles; transient range 568 square miles.

Up to the period of settlement, the herd probably migrated annually down to the surrounding plains. Since the establishment of the park, the larger mammals have become isolated on the escarpment by the agricultural development on the surrounding prairies. There are now in winter only local concentrations of herds on favorite feeding grounds.

On October 6, 1947, there was an unseasonable fall of 22 inches of snow. Thereupon large numbers of elk moved down from the mountain on all sides and entered the lower farmland, where they found unguarded many fields of stooked grain and haystacks. They did a good deal of damage before they drifted back into the park, when the snow melted.

POPULATION

In order to arrive at some estimate of the population density of the elk, strip counts were made during the winter and spring periods from the roads and trails. The counts were made by car, by sleigh and on foot, and during early morning or evening periods. The length of strip and average width of visual field were recorded and the elk per square mile were calculated. When several counts were made along one route, the highest count was used. The strip counts are recorded in Table 1. They indicate a winter population up to 77 elk per square mile on the concentrated elk ranges. By spring the population density had dropped, on account of the heavy winter kill, to 58.7 elk per square mile.

The total number of elk observed during both periods, classified by age and sex, are listed in Table 2.

The first newborn calf was observed on May 30, 1947. The 1947 herd incre-

FIG. 1.—Map of Riding Mountain National Park, Manitoba, indicating the Elk range.

ment, calculated as the percentage of calves to cows observed after May 30, was 23.7 per cent. This ratio represents a poor calf crop when compared to the survival of the 1946 calf crop to January 1947. This latter age class was then 34.1 per cent of the cows. It is suggested that the severe winter conditions affected the calf crop by losses of pregnant cows (several observed), still births (one was found), and by re-absorption of embryos.

The heavy winter mortality among the rising yearling class is indicated in Table 2. In January, this class totalled 23.4 per cent of the herd. By May, it was reduced to 8.5 per cent of the herd. This means that 63.6 per cent of the 1946 calves which survived until January perished before May, 1947,

Some data on the secondary sex ratio were collected. A number of newborn calves were captured and eartagged. Of the 10 calves examined, 8 were females. This is only a small sample, but it suggests a possible high prenatal mortality among the males.

TABLE 1.—WINTER AND SPRING, 1947 STRIP COUNTS OF ELK

Area	Winter Observations		Spring Observations	
	Elk observed	Elk per square mile	Elk observed	Elk per square mile
Norgate Road	92	77	25	26.8
Dauphin Road	141	113	18	34.9
Clear Lake	83	105	28	55.0
Lake Audy	52	46.5	230	97.0
Baldy Lake	52	102		
Whitewater Road			25	72.7
Whitewater Lake			52	65.8
Russell Region	13	19.1		
Average		77.1		58.7

TABLE 2.—CLASSIFICATION OF OBSERVED ELK DURING WINTER AND SPRING, 1947

Season	Bulls		Cows		R2* Bulls		R2 Cows		Yearlings		Calves		Total
	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.	Pct.	No.
Winter	40	*6.7*	389	*65.2*	12	*2.0*	16	*2.7*	138	*23.4*	0	*0*	595
Spring	26	*6.9*	286	*76.0*	8	*2.2*	12	*3.2*	32	*8.5*	13	*3.2*	377

* R2 means rising two year old.

WINTER KILL

During this investigation 59 carcasses resulting from starvation were found. Many more were reported by the wardens, who found 179 in the month of April alone.

Strip counts were also used for recording elk carcasses found, as a means of estimating the loss due to winter kill. It was found that the strip counts indicated that, on each square mile of densely occupied range, an average of

15.2 elk died. Compared with the counts of live elk, which gave an average figure of 58.7 elk per square mile, this indicates an estimated 20.5 per cent mortality occurring that winter.

adult incisors are erupted during the second summer and additional pairs of incisors each succeeding summer, until the fourth and final pair are erupted during the fifth summer. These age

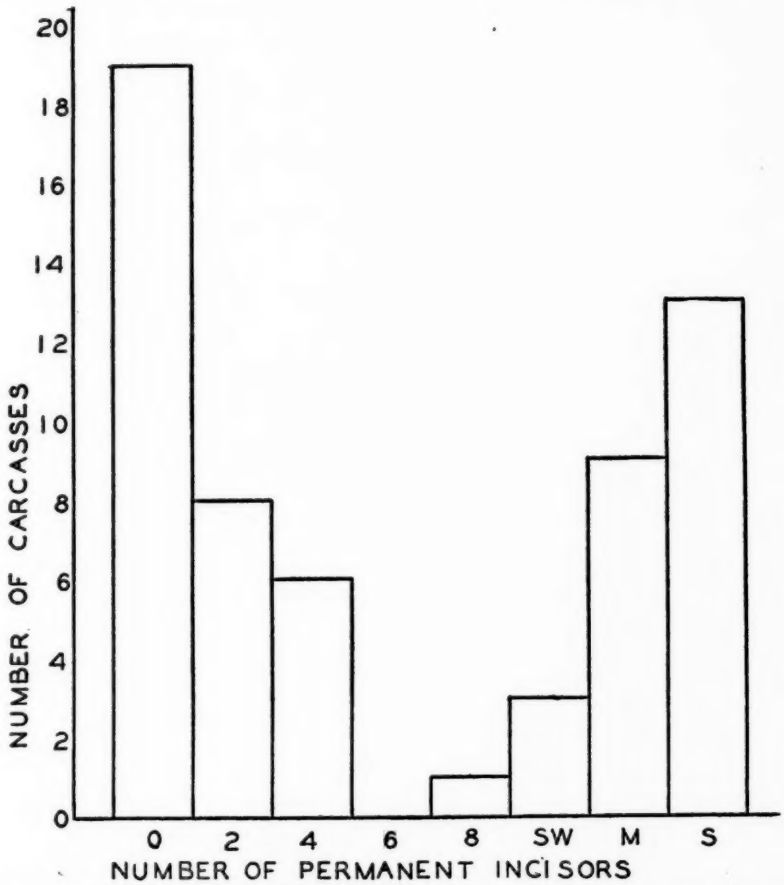

FIG. 2.—Winter mortality, 1946–47, showing relationship between winter loss and age as determined by tooth examination. SW = incisors show slight wear; M = mature; S = senile.

In connection with the elk reduction program at Banff National Park, H. U. Green has developed a method of determining the age of elk by observing the state of eruption of the permanent incisors. It appears that the central

classes were in agreement with other age criteria such as body measurements and antler development, as far as these could be followed, and are similar to age determination methods for domestic animals, such as sheep and cattle.

This method was used to classify tentatively the carcasses found. As the elk succumbed during March and April they were classified as rising first year, rising second year, up to the fifth year, by the number of permanent incisors. A further age class was recognizable by having all the permanent incisors slightly worn. Above these classes they were classified as mature or senile. If the carcasses showed excessively worn teeth accompanied by long skulls, abnormal antlers, poor coat and worn hooves, they were classified as senile animals.

The classification of the carcasses observed by age groups is given in Figure 2. The high mortality among the earliest age groups and the senile class is clearly indicated. The resistance of the young mature animals is also shown.

PARASITOLOGY

The elk herd harbored a heavy infestation of winter tick (*Dermacentor albipictus*). The majority of carcasses examined showed moderate to heavy degrees of infestation. When a heavy infestation was encountered, the ground and vegetation for several feet around the carcass were inhabited by active ticks.

An adult female elk which was taken for pathological examination had a heavy infestation of biting lice, which strongly resemble the horse-biting louse (*Bovicola equi*). The elk showed a thin, patchy pelage, with scaly areas of hide most prominent on the rump. Many other elk had the same rough-coated appearance, suggesting that the infestation was widespread.

TABLE 3.—COMPOSITION OF THE BROWSE VEGETATION BY SURVEY

Species	Height in Feet	No. Per Acre		Pct. Occurrence		Pct. Utilization	
		A	B	A	B	A	B
Aspen	−10	940	448	*52*	*22*	Alive *24* Dead *76*	*28.5* *71.5*
	+10	640	64	*25*	*3*	Chewed *69.0* Broken *5.5* Dead *7.8*	1 *0* *0*
Willow	− 7	670	96	*40*	*3*	Alive *94.5* Dead *4.5*	*100*
	+ 7	50	0	*5*	*0*	—	—
Dwarf Birch	− 3	520	32	*25*	*3*	—	—
Dwarf Birch	+ 3	640	—	*24*	—	—	—
Hazelnut		150	128	*6*	*6.3*	—	—
Saskatoon		410	160	*21*	*9.5*	—	—
Shrubby Cinquefoil		240	32	*16*	*3*	nil	nil
White Spruce		50		*4*		nil	nil
Rosa		1210		*34*		nil	nil
Elk defecations		830	512				

A refers to Clear Lake quadrats; B refers to Whitewater Lake quadrats.

Of the two elk collected for examination, both contained heavy infestations of hair lung worm (*Dictyocaulus viviparous*) in the bronchioles and bronchi. It was thought that this condition of verminiferous pneumonia was also widespread in the Riding Mountain herd.

Although the actual primary cause of death in these winter kills was probably starvation, it is likely that there was a condition of general debility in the herd, brought on by the heavy parasite infestations, and that this condition was an important secondary lethal factor.

BROWSE STUDIES

A browse survey was made during early May of two park areas which are important winter elk ranges. The method of study consisted of surveying milacre quadrats, mechanically selected at regular intervals on transects of the range. In each plot the number, height, and condition of the browsed species were noted. The number of plants is reported as the number per acre. To facilitate the comparison of the relative abundance of the plant species on the two areas, the number of plots in which a species occurred have been totalled and divided by the total number of plots surveyed and the ratio multiplied by 100 to give a percentage. This figure appears in the column of per cent occurrence in Table 3. The utilization of the aspen and willow has been recorded as percentages of the plants that have had the bark stripped off or have been broken or killed by severe browsing. In order to establish a basis for the analysis of relative utilization of the two ranges, counts were made of the number of elk defecations in the sample quadrats. These are recorded as defecations per acre. An inspection of the data presented in Table 3 clearly indicates the destructive utilization of aspen which has taken place.

In order to study the productivity and utilization of the available browse,

TABLE 4.—COMPARISON OF BROWSE PRODUCTIVITY IN UTILIZED AND NON-UTILIZED AREAS

Species	Stems	Golf Course Average		Elk Range Average	
		Number	Weight	Number	Weight
Aspen	Alive Dead	3 0	11.0 gms.	3.3 0	13.0 gms.
Dwarf birch	Alive Dead	53 20	92.8	92 21	120.9
Hazelnut	Alive Dead	155 31	195.8	118 27	147.0
Saskatoon	Alive Dead	5.5	16.0	2 0	2.3
Total Annual Growth			157.8 gms.		144.4 gms.
		Average height aspen =6′ shrubs =4′6″		Average height aspen =2′ shrubs =2′6″	

milacre quadrats of shrubs were delimited. Four quadrats were clipped within the golf course enclosure at Clear Lake, where the elk have been excluded for several years. Three additional quadrats were clipped from the heavily utilized winter range outside the enclosure.

The quadrats were chosen arbitrarily to illustrate average densities of available browse plants in both locations. In each case the number of stems was counted and the growth of the previous year (1946) was clipped and weighed. This consisted of all the buds and the tips of the twigs down to annual rings indicating the location of the previous year's bud scales.

The plants within the enclosure showed the typical growth form of the various species. The plants on the nearby game ranges were stunted, due to heavy browsing. The comparison of the productivity at the two sites is given in Table 4. Despite the visual difference in the form of the shrubs, the proportion of dead to living stems was similar in both sites. The amount of annual growth left after browsing was of the same order as the total annual growth in unbrowsed plants of hazelnut and dwarf birch. This means that before browsing occurred in the winter of 1946–47, the 1946 annual growth on the plants subsequently browsed was greater than on plants not subjected to browsing. It appears that both of these species can stand heavy browsing. The browsing appears to act like pruning, which promotes a vigorous adventitious growth of new buds and twigs the following season.

SUMMARY

The present status of Manitoba elk (*Cervus canadensis manitobensis*) in Riding Mountain National Park, Manitoba, was investigated during the winter and late spring of 1947. It was found that the severe winter conditions of 1946–47 had caused an estimated drop from 77.1 to 58.7 elk per square mile on the concentrated elk ranges, which are estimated to total 180 square miles. This means an estimated mortality of 20 per cent, due to winter kill. The rising yearling age class had the heaviest loss, 64 per cent. An analysis of the 59 carcasses examined showed that the youngest and senile classes suffered the greatest losses. There were widespread infestations of external and internal parasites.

The high population of elk caused severe damage to the aspen stands. As high as 76 per cent of all aspen under 10 feet in height have been killed in certain areas, while 69 per cent of the aspen more than 10 feet in height had had part of the bark peeled by elk.

Certain shrubs, such as dwarf birch (*Betula glandulosa*) and hazelnut (*Corylus americana*) apparently are able, because of stimulated adventitious growth, to withstand heavy browsing.

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DEER AND RABBIT BROWSING AND AVAILABLE WINTER FORAGE IN ALLEGHENY HARDWOOD FORESTS

A. F. Hough[1]

Those dealing with wildlife management are aware of the problems created when overpopulation by deer occurs in a given locality such as the Kaibab plateau in Arizona, portions of the Lake States, central and northern Pennsylvania and the Adirondacks of New York. Lack of balance between the deer population and its food supply can easily result when predators are few or are strictly controlled and when hunting pressure is inadequate to remove surplus animals.

Scarcity of forage for deer during the critical winter months has long been a problem in the central and northern counties of Pennsylvania. In 1937 Seth Gordon issued a timely plea for understanding by the sportsmen of the need for control of an excessive deer herd by removing female as well as male deer during the hunting season. The situation was practically out of hand, however, and starvation losses cut heavily into the deer herd on areas where past browsing had depleted the available forage plants.

As early as 1930 deer on the southern half of the Allegheny National Forest "were so numerous that their needs far exceeded the long term forage supply" (McCain, 1941). By 1938 this forest, with a gross area of 739,000 acres, supported about 50,000 deer, or roughly one animal to 15 acres. A record kill of 24,000 does during the 6-day season of 1938 reduced this surplus. "This legal kill was even larger than the total that most sportsmen had been willing to admit existed in the area, yet nearly two animals remained for each one killed" (McCain, 1941). Despite this reduction 4,500 deer died of cold and starvation during the winter of 1938–39. Through subsequent hunting and starvation this peak population on the Allegheny has been reduced to about 16,000 deer, an average of one deer to 46 acres in 1946.

Large concentrations of deer are known to shelter on the south- and west-facing lower slopes and valley bottoms during the severe winter months (Ehrhart, 1936). It is only natural that repeated browsing tends to kill back most of the available low cover of food plants on such sites. Past heavy use has reduced or removed many of the favored browse species and has created a so-called "deer line" on larger tree growth, particularly in these valley bottom areas. How much of this damage is actually due to the activities of deer and how much to other animals cannot be determined by general observation.

While the deer population was building up to its peak, four half-acre plots in different stands on the Kane Experimental Forest were fenced against deer and half of each enclosure was also fenced to keep out rabbits. This work was done in the fall of 1935. During the next growing season a complete census of all tree growth 1.0 foot in

[1] Northeastern Forest Experiment Station.

height and taller was made on the fenced plots and on adjacent unfenced check areas. The object of this study was to determine the effect of browsing by deer and rabbits on the density, species composition, and growth of natural tree regeneration in four hardwood stands. Of chief interest was the reaction of existing and future tree reproduction to changes created by the exclusion of these animals. No attempts were made to study the feeding habits or density of the animal population as such.

The Kane Experimental Forest is located in north central Elk County not far south of the McKean County line and is thus about half way between the north and south boundaries of the Allegheny National Forest. Concentrations of one deer to 10 or 12 acres were found in 1935 and 1936 in the heavily logged and burned stands of the southern district, with an average of one deer to 14 acres. On the better-forested northern district 18–30 acres per deer was more common, with an average of 22 acres (Park, 1938). Deer population on the Kane Forest was probably somewhere between these two extremes during the period of this study.

RESULTS OF EXCLOSURE STUDIES

The 1936 examination of the fenced and check plots gave certain information about the woody food plants used by deer and rabbits, and degree of browsing in different habitats. Records of deer and rabbit browsing[2] were made on all tree regeneration1.0 foot in height to 0.5 inches d.b.h. on 4 acre of plots. "A statistical analysis of this data showed that differences in species susceptibility were significant in the case of rabbit injury, but not in the case of deer injury" (Ostrom, 1937). The analysis indicates that rabbits are more discriminating in browsing than deer. They make use of significantly more red maple[3] than any other tree species. They browsed only slightly on hemlock, but beech and sugar maple were evidently staple food plants. Black cherry ranked fourth in order of preference.

Deer browsed 29 per cent of all red maple reproduction, and 29 per cent of all hemlock. They also browsed black cherry (26 per cent), sugar maple (20 per cent), and beech (13 per cent).

Under an old-growth beech-sugar maple forest rabbit browsing was found on only one per cent of 3,593 trees and deer browsing on 0.1 per cent, of 2,193 trees examined in 1936. Both deer and rabbits frequented this stand but browsing use was spread out over the abundant understory of tolerant seedlings present and thus was low in terms of percentage. Greatest use by deer occurred in the lower slope second-growth area, where 47.7 per cent of all tree reproduction was browsed; next heaviest was under a similar stand on the plateau, where 26 per cent was browsed. Rabbits had browsed 23 per cent of all tree reproduction in a poorly forested depression or valley head and lesser amounts in the two second-growth stands where low browse was somewhat less abundant.

When these deer and rabbit exclosures were reinventoried in 1941, strik-

[2] Tooth marks and clean slanting cuts indicate browsing by rabbits; deer break and tear the tissues in a manner easily distinguished from rabbit use (Pearce, 1937).

[3] Red maple suffered 90 percent damage by snowshoe rabbits in small patches of hardwood in older spruce-hardwood stands in Maine, according to Pearce and Reineke (1940).

ing changes in the density of the tree reproduction had taken place, especially in the two second-growth stands that were fenced against both deer and rabbits (Ostrom, 1942). An increase of 232 and 305 per cent over the original number of seedlings had occurred on the lower slope and plateau second-growth sites that had received full protection for 5 years. Contrary to expectations, but of great importance, was the finding that protection against deer alone caused an insignificant increase in seedling abundance. The deer herd had reached peak numbers during this period 1936–41 and yet, in second growth on the Kane Experimental Forest, the results showed that rabbits were more active than deer in consuming browse and holding back the development of an understory of low cover. The 1941 figures also show that density of tree reproduction beneath old-growth forest increased regardless of any natural mortality of reproduction or damage by animals. Reproduction density declined in the semi-open stream valley, but to a less degree inside than outside the fences (Ostrom, 1942).

In 1946, 10 years after fencing, three of these exclosures and the adjacent unfenced check plots were retallied to determine changes in the density and species composition of woody browse.[4]

The total number stems per acre[5] as of 1936 and 1946 are compared graphically for each area in figure 1.

DISCUSSION

The critical winter supply of forage for deer on forested slope and valley bottom sites could be greatly improved by protection from, or control of rabbits. Heavy rabbit browsing is found beneath densely stocked second-growth forests on north-facing lower slopes and well-forested valley bottoms, as well as in more open sites. The interrelationships between such game animals as deer and rabbits are thus seen to be very important, since both depend on the same supplies of browse during the period of deep crusted snows when they concentrate on sheltered lower slopes and valleys. Present conditions, with regard to forage for wildlife in practically all such sheltered valleys on the Allegheny Plateau, are pitiful and winter starvation losses of deer will continue unless some way can be found to increase the abundance of native food plants.

It is not the purpose of this article to discuss methods or costs of rabbit control. The important thing for managers of land and wildlife in the Allegheny Plateau region to recognize is the dependence of both deer and rabbits on the same winter browse and the fact that over-populations of either are harmful to the continued production of the vegetation on which they subsist. Control of the rabbit populations in valley bottoms occupied by over-wintering deer will be quite expensive if special rabbit-proof fence must be erected and maintained over large areas of land. Increased hunter pressure in critical areas combined with control of rabbits by predators seems more

[4] Time did not permit a retally of the old-growth beech-maple forest plots. Observations indicate small advance-growth seedlings are still very abundant and no great differences in density apparent as a result of fencing.

[5] Includes tree seedlings, sprouts and root suckers 1.0 ft. tall to 0.5 inches d.b.h. as well as reproduction of certain shrubs such as mountain holly, witch hazel, and hobble bush.

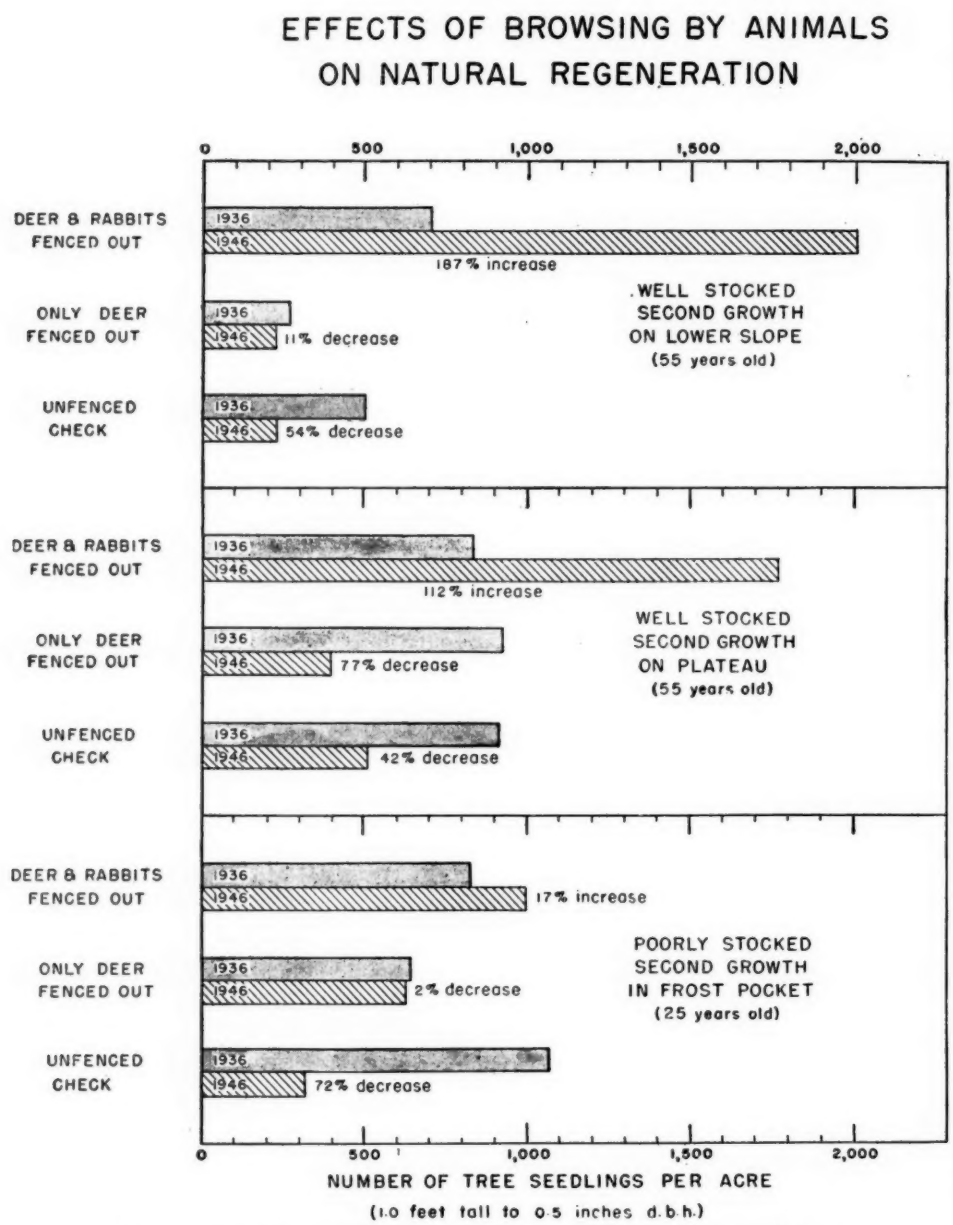

FIG. 1. A graphic example of how animal browsing affects re-vegetation.

promising. The latter may be obtained by reduced trapping of certain fur bearers such as mink, weasel, and fox. Cycles in the rabbit population are well known, and it is probable that control measures will be less necessary during the low than the peak periods.

This study indicates that increase in the available browse can be expected to take place 5 to 10 years after complete

protection from both deer and rabbits in well-stocked second-growth stands. If deer continue to browse in normal numbers, this period may be slightly lengthened. No data are available on range recovery under other degrees of use. Witch hobble (*Viburnum alnifolium*) made a marked recovery in the dense north-facing lower slope forest when given complete protection from deer and rabbits for 10 years. When protected against deer only, the few remaining plants suffered further losses similar to those on unprotected plots and now few living stems are to be found. Heavy browsing had already eliminated this key species on the plateau and 10 years' protection did not bring in any new plants. Rapid recovery of winter deer range is thus possible if there remains a nucleus of living witch hobble to respond to rabbit control measures.

Recovery of browse species in poorly forested stream valleys is, however, much slower even though both deer and rabbits are excluded. A 17 percent increase in abundance is all that occurred on the completely protected plot over a 10-year period. A detailed study of the climatic and biological factors responsible, indicates that extremes of temperature, and competition from the heavy weed cover, are serious detriments to the growth of tree reproduction in addition to the damage by animals (Hough, 1944). Since the action of late spring frosts on the existing vegetation is one of the striking phenomena in these open valley bottoms they have been called "frost pockets."

APPLICATION TO WILDLIFE MANAGEMENT

Those in close contact with the problem of deer management in Pennsylvania and southern New York generally admit the situation is still serious and that controls by the legal harvest of surplus deer are still necessary. Search is still going on for economic methods of improving the habitat for deer and other wildlife, especially in areas of past overpopulation. Such measures as artificial feeding in winter, planting food patches, and cutting trees to supply tops for starving deer, are at best short-term or stop-gap solutions. It has been suggested by Freeburn (1945) that modification of even-aged second-growth stands by clear-cutting of cordwood products on short-cutting cycles will provide needed food and low cover for big game species such as deer. This solution is short sighted, even if applied only to State Game lands, since both forest and game production will eventually be greatly impaired by such practices.

"The population of whitetail deer in Allegheny National Forest is again on the upswing and this should be recognized as a dangerous condition," according to Swift (1946). While thinnings for chemical wood are known to improve second-growth stands, both for future saw-timber production and as a habitat for wildlife (Hough, 1946), it is possible that this market may fold up quickly because of competitive disadvantage of the wood distillation industry in the postwar period.

"Loss of this market will make more difficult the use of commercial sales of low-grade products as a tool for better forest and wildlife management. Much of this forest has already passed the stages where tree reproduction is within the reach of deer, and thinnings or weedings to stimulate the development of a low cover of browse are essential if the increased deer herd is to be maintained."

The new evidence from deer and rabbit exclosures on the Kane Experimental Forest points the way for providing much additional forage for deer even if lack of labor, poor markets, or other conditions make thinnings or other operations to change the forest canopy uneconomic. Control of the rabbit population on limited areas of winter range can be expected to do much toward speeding up the recovery of browse on areas depleted by past misuse.

Where markets of pulpwood and chemical wood permit, a combination of natural predator control of rabbits and stand improvement thinnings will give maximum results in building up winter browse, increasing forest productivity, and providing a solid economic base for forest industry and stable communities in this region. To make the largest contribution to restoration of depleted deer range, these treatments should first be applied in well stocked stands on lower slopes and sheltered valley bottoms. It is here that deer and rabbits concentrate and require both food and shelter when deep crusted snow and below-zero weather blanket the Northern Allegheny Plateau.

SUMMARY

Rabbits damage the low cover of tree and shrubby browse beneath second-growth Allegheny hardwood forests to a much greater extent than deer. Under complete protection a remarkable recovery of the browse species takes place in 5 to 10 years. Only slight recovery took place when deer alone were excluded. Efforts should be made to control the rabbit population in lower slope and valley bottom sites used for winter range. This alone would go far toward building up a supply of of browse vitally needed by deer during the period of deep crusted snows when starvation losses are high. Partial cuttings, leaving a protection canopy, will accelerate the increase in density and height growth of this low browse cover.

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REVIEW

Salmon Fishing. A New Philosophy. By Richard Waddington. New York, Charles Scribner's Sons. 199 pp., illus. 1948. $4.50.

This book is written for the Atlantic salmon fisherman and contains little factual information for a fisheries biologist. The author's theories are based mainly on his observations and experiences on salmon rivers in Scotland. In the foreword the author states that much of what he has written may be heresy and that many of his deductions may be false.

The author assumes the salmon to be a marine fish and that it retains at moments in freshwater its sea behavior of feeding. The salmon has the habit of searching and seizing food at sea, and under certain conditions in freshwater, it presumably returns to this habit and rises to a fly. The various conditions governing this moment are postulated as well as the proper size of fly to use.

The increase in the freshwater eel is believed by the author to be of importance in reducing the salmon in the rivers of northeastern Scotland. This increase, he says, has possibly come about through the disuse of eel traps in that section of Scotland since World War I.

The reader will find some interesting information regarding the methods employed in Scotland on the operation of the sport salmon fishery. The costs one incurs for the right to fish Scottish salmon rivers as well as other types of streams on the continent should make the reader better realize the problem we face in America with our increasing fishing demands and pressure.—WILLIAM C. STARRETT.

NOTE

"A List of Common and Scientific Names of the Better Known Fishes of the United States and Canada" has been published by the American Fisheries Society (Special Publication No. 1, Ann Arbor, Michigan, 1948, 45 pp.). This pamphlet is a result of the work by a committee appointed in 1933. The committee has submitted a list in systematic order of 571 fishes with one common name for each fish and the generally accepted scientific name. All common names considered and an index of the scientific names in the main list are included. It is available to non-members of the American Fisheries Society for 25 cents per copy from Dr. William C. Beckman, librarian, Museums Annex, Ann Arbor, Michigan.

Coincidentally, the day that this publication came across the Editorial desk, a similar list also arrived. This second publication is titled "Standard Check List of Common Names for Principal American Sport Fishes," compiled by the Outdoor Writers Association of America. Single copies are available free of charge, and quantities can be obtained for cost of postage plus 25 cents for packing. Requests should be directed to OWAA Headquarters, 10 East Lexington Street, Baltimore 2, Maryland.

The two lists are aimed at two audiences. The first is an attempt to stabilize common names for the great majority of fishes of the United States and Canada, 571 forms being included. The second has the same objective for that rather loose group known as sport fishes. It lists 214 species.

In general, the common names in the two lists are identical. Where variations occur, they are often in the dropping of one word in a double adjective, as largemouth bass vs. largemouth black bass. Some more important divergences unfortunately occur, for instance, in the common names of the salmon.

Both lists will be of value to aquatic biologists.—HARLOW B. MILLS.

BRIEFER ARTICLES

THE EFFECT OF SHADING UPON SEED PRODUCTION OF THE TRAILING LESPEDEZA

During the years 1940 and 1949, a survey of ground cover was made in conjunction with the timber type mapping work that was conducted on the Kentucky Woodlands National Wildlife Refuge. One object was to learn the effects of the degrees of openness in the forest canopy on the ground cover and particularly upon plants of value as producers of wild turkey food. While it was believed that study plots distributed throughout the area would give a good idea of the density of ground cover in relation to crown density, it was felt that this would not tell the whole story in regard to seed production. The question arose as to what effect exposure to sunlight might have upon the production of seed.

Collections were made from the white oak-black oak-hickory timber type, the most common timber type on the two refuges. Samples were collected from differently shaded areas and estimates were made of the crown density at each collecting site. Each sample was weighed at the time that it was collected before there was any loss of weight from drying. These samples, fourteen in number, averaged 88 grams with one weighing as high as 309 grams and another as low as 14 grams. The fruits were stripped from the stems, air dried, cleaned, and weighed.

The following tabulation summarizes the information obtained under the standard crown density groups:

Per cent Crown Density	Number of Samples	Total Weight of Samples in Grams	Weight of Fruits Average of Totals %	Weight of Fruits Mean Percentage
0– 10	1	309	*6.6*	*6.6*
11– 40	4	249	*6.3*	*6.3*
41– 70	5	475	*5.9*	*5.3*
71–100	4	190	*4.9*	*3.8*

Thus, if a certain unshaded area had, say, five times as much ground cover as an otherwise comparable but shaded site, it might not necessarily follow that the seed production would be five times as great.

To test this, a small series of samples of the vines of the trailing lespedeza (*Lespedeza procumbens*) was collected on the Tennessee National Wildlife Refuge in mid-October, 1947. This plant is a common native woodland legume whose seeds are important as food of gallinaceous birds. It is believed that the time of collecting was late enough in the year to allow nearly all the seed to mature, and yet it was before frost had killed the leaves or caused the fruits to drop off.

From these data the indications are that the percentage of the weight of seeds in a given amount of vine decreases in proportion to the amount of shade. Thus an unshaded area, which had five times as much ground cover of trailing lespedeza as a comparable but shaded area, might be expected to have 8.6 times, instead of five times, as much seed. That shading inhibits seed production of this wild legume to a greater extent than it inhibits its total growth of the plant is in accord with common knowledge among farmers that shading decreases seed production in the cultivated lespedezas even more than it decreases hay production.—EUGENE CYPERT, *U. S. Fish and Wildlife Service, Paris, Tennessee.*

ACCEPTANCE OF SEEDS OF FOUR LEGUMES BY THE BOBWHITE QUAIL

From time to time there have been inquiries about the food value or toxicity of seeds of certain legumes for quail in the wild. In order to obtain answers for such questions, short-time tests on small lots of the seeds under question were conducted with pen-reared quail at the Patuxent Research Refuge, Laurel, Maryland. The tests were primarily on four legumes: *Lespedeza juncea*, Caley pea (*Lathyrus hirsutus*), blue lupine (*Lupinus angustifolius*), and mung beans (*Phaseolus mungo*).

Test No. 1, Lespedeza juncea: For the period of one week, two groups of six quail each were given the choice of seeds from *Lespedeza juncea*, shrub lespedeza (*Lespedeza bicolor*), and partridge-pea (*Cassia chamaecrista*), the last two being recognized as good quail foods. All three foods were unfamiliar to the bobwhites on test. The selection made by the quail is given in Table 1. The *Lespedeza juncea* was accepted but not to the same extent as the other two items. Nearly four times as much shrub lespedeza was taken, and over twice as much partridge-pea.

TABLE 1.—SELECTION OF SHRUB LESPEDEZA, *Lespedeza juncea*, AND PARTRIDGE-PEA SEEDS BY BOBWHITES

Name of Food	Total Eaten (grams)	Per cent of Diet
Shrub lespedeza	398	*57.6*
Partridge-pea	200	*28.9*
Lespedeza juncea	93	*13.5*

Test No. 2, Caley pea and blue lupine: For the first part of the test, seven pens of six adult quail each (3 of each sex) were used. The basic diet contained ground yellow corn, two per cent alfalfa leaf meal, one per cent steamed bonemeal, one per cent salt mixture, and 0.5 per cent vitmains A and D feeding oil fortified. To this were added blue lupine and Caley pea seeds at levels of 25, 50 and 75 per cent in comparison with soybean oil meal at 25 per cent. The pens receiving the lupine seeds at 50 and 75 per cent levels were discontinued after two weeks because of the poor feed consumption, and those receiving Caley peas at similar levels were discontinued at the end of three weeks. The remaining three pens were carried to the end of four weeks. Results at the end of two weeks are shown in Table 2. At the completion of the test, the birds on 25 per cent soybean meal showed a loss of 9 grams from their initial weight; those on 25 per cent Caley peas, 15 grams, and those on 25 per cent blue lupine, 26 grams. There was no mortality.

TABLE 2.—LOSSES IN BODY WEIGHT AND FEED CONSUMPTION OF QUAIL ON CALEY PEAS AND BLUE LUPINE AT END OF TWO WEEKS

Diet	Grams Loss in Weight	Grams Feed per Bird per Day
25% soybean meal	7	13.4
25% Caley peas	13	11.8
50% Caley peas	18	12.2
75% Caley peas	24	13.6
25% blue lupine	5	11.2
50% blue lupine	30	8.5
75% blue lupine	59	6.4

Thus in a ground state and as part of a mash, Caley peas were eaten more readily than blue lupine seed, especially at levels of 50 and 75 per cent of the diet. In fact at these levels, the lupine seed seemed to be very unpalatable to the quail. Although Caley peas could not maintain the weight of the birds so successfully as the same level of soybean meal, nevertheless, they did maintain it better than blue lupine seed at a similar level.

For the second part of the test, three pens of six birds each were given the following choices of foods: Pen 1—Ground Caley peas, ground lupine seed, and ground corn; Pen 2—Whole Caley peas, whole lupine seeds, and whole mixed grains; Pen 3—Mash with 25 per cent Caley peas, mash with 25 per cent lupine seed, and mash with 25 per cent soybean meal. According to Table 3, slight preference was shown the whole lupine seed over the whole Caley peas, but both in Pens 1 and 2 the main preference was shown for the grains. Nevertheless in Pen 3 the diet con-

taining 25 per cent of Caley peas was consumed in greater quantity than either of the other two diets, especially that containing 25 per cent of blue lupine seed which was not even touched.

TABLE 3.—SELECTION BY QUAIL OF CALEY PEAS AND BLUE LUPINE AS AGAINST GROUND CORN (PEN 1), WHOLE MIXED GRAINS (PEN 2), AND SOYBEAN MEAL (PEN 3). FIGURES REPRESENT PERCENTAGE OF TOTAL DIET

Pen	Caley Peas	Blue Lupine Seed	Grains or Soybean Meal
1 (ground seeds)	*0*	*1*	*99*
2 (whole seeds)	*5*	*9*	*86*
3 (mash)	*55*	*0*	*45*

The study indicates that both foods can be used by quail without being toxic, but neither is a preferred article of diet. In the ground state, however, and in large quantities, lupine seeds are seemingly very unpalatable. An analysis for tannin might reveal the cause of this.

Test No. 3, mung bean: According to Allen M. Pearson and D. G. Stuckie, in their article entitled "Food Crops for Game Birds on Farm Lands" (Ala. Agri. Exp. Sta. Cir. No. 90, June 1944, p. 10), the exotic mung bean "is similar in many respects to cowpeas and soybeans. It may be grown successfully in all parts of Alabama, and usually produces a satisfactory seed crop. Most of the seed scatters soon after ripening. This species apparently is suited for annual planting, and it may be substituted for cowpeas or soybeans with comparable results."

Over a two-week period six adult quail in one pen were given a choice of mung beans as against five recognized quail foods, Augusta vetch (*Vicia angustifolia*), shrub lespedeza (*Lespedeza bicolor*), *Lespedeaz juncea*, black locust (*Robinia pseudo-acacia*), and Partridge pea (*Cassia chamaercista*). All six foods were unfamiliar to the quail on test. Mung beans were the first choice of the birds, comprising 54.7 per cent of their diet, and shrub lespedeza was second at 35.7 per cent of the diet. The other four foods were chosen as follows: Augusta vetch, 5.0 per cent of the diet; black locust, 3.7; *Lespedeza juncea*, 1.3; and partridge-pea, 0.7.

For the second two-week period the same birds were given a choice of whole mung beans and cracked corn. Mung beans were made 44.5 per cent of the diet, and corn 55.5 per cent.

During a third two-week period the quail were given a choice of cracked yellow corn, whole mung beans (unweathered as in the other selections), and whole "weathered" mung beans. The "weathering" of the beans was achieved by wetting them at room temperature until they started to sprout, and then drying and freezing them. This process was repeated several times and then the beans were subjected to a final drying. The selection was as follows: Cracked corn, 53.3 per cent of diet; unweathered mung beans, 26.7; "weathered" mung beans, 19.9. Apparently the unweathered bean was preferred over the "weathered" bean.

Mung beans have an unusually high carotene content, 2990 I.U. per 100 grams for the variety raised in the U. S., and 1950 I.U. for the variety imported from the Orient. "Weathered" domestic mung beans, however, lose carotene rapidly. Beans having 2990 I.U. before being "weathered," showed only 1080 I.U. per 100 grams after ten days of severe "weathering."

The riboflavin content of mung beans is about 80 micrograms per 100 grams. A chemical analysis of the domestic variety is as follows: crude protein, 20.4 per cent; ash, 3.4; fat, 1.4; fiber, 4.2; nitrogen-free extract 60.9; calcium, 1.0; phosphorus, 0.45.

The mung bean might become a valuable quail food if a strain can be developed that will not shatter too soon after ripening.—RALPH B. NESTLER, *U. S. Fish and Wildlife Service, Laurel, Maryland.*